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Maine Agricultural Experiment Station

ORONO

BULLETIN No. 189. APRIL, 1911

ORCHARD SPRAYING EXPERIMENTS.

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CORRECTIONS FOR BULLETIN 189.

The Station bulletins are printed from linotype. After the proof was read in transferring from galley to page three transpositions of lines were made by the printer which escaped attention. These are as follows:—At the bottom of page 37 the line following the note should precede it. On page 58 the line at the bottom of the page should follow the second line under *"Effect on Fruit"* about midway of the page. On page 67 the next to the last line should precede the line above it. Also on page 37 near the bottom for "inhibition" read "inbibition."

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BULLETIN No. 189

ORCHARD SPRAYING PROBLEMS AND EXPERIMENTS: A REVIEW OF, AND A CONTRIBUTION TO PREVIOUS DATA.

W. W. BONNS.

The spraying of economic plants for the control of insect and fungous enemies has markedly increased within the past decade. This is largely due to the work of experiment stations in demonstrating the effectiveness of the operation and the profit attending it. Great improvements in spray machinery and materials have helped much towards the adoption of spraying as an annual farm operation, and especially is this true of the fruit growing industry. The progressive orchardist today recognizes the necessity of timely, thorough and intelligent application of insecticides and fungicides in order to sell his fruit in the best and most profitable markets.

SPRAY INJURY.

The increase of spraying operations has, however, been accompanied by serious problems for the solution of which the grower turns to the experimenter. The use of bordeaux mixture, for many years the standard orchard spray, and even today recognized as the best all-round fungicide known, has been accompanied by injury to fruit and foliage.

Complaints of such injury have been increasing with each season and are not confined to any section of the country. The severity of the injury varies in degree and in different seasons. It has long been known that bordeaux mixture cannot be used with safety on the peach and Japanese plum when the tree is in leaf, although Cordley and Cate report the use of 5-6-50 and 3-6-50 formulae on peach foliage without injurious results.*

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* Cordley, A. B. and Cate, C. C. "Spraying for Peach Fruit Spot." Oregon Agric. Expt. Sta. Bulletin 106 (1909), p. 11.

On the apple and pear the injuries have manifested themselves in two ways,—burning and spotting of the leaves and russeting or "corking" of the fruit.

The leaves so affected show dead brown spots, similar in general appearance to some leaf spots produced by fungi and especially to those of the fungus causing black rot and canker of pomaceous fruits (*Sphaeropsis malorum,* Pk.). These spray injury spots are generally circular or roundish, though often irregular. Frequently the areas are large, as if a number of smaller ones had coalesced. Occasionally the margins of the leaves show the characteristic dark brown or blackened dead tissues (Fig. 47).

Such foliage injury is very frequently followed later in the season by yellowing and premature leaf fall. This occurs early or late according to the severity of the injury; in some seasons it is absent. That this phenomenon is the direct result of using bordeaux mixture or other sprays has not been fully proved, but the frequency with which it accompanies spray injury tends to establish a correlation between them.*

On the fruit the injury is first seen as small, dark, fly-speck like spots. These are not to be confused with infections of the scab fungus (*Venturia Pomi* (Fr.) Wint.) or with the fly speck fungus (*Leptothyrium Pomi* (Mont. and Fr.) Sacc.). The former are regular, smaller,—about one millimeter diameter,—and not sunken. The final appearance of the fruit is well known to nearly all orchardists with experience in spraying. The skin is washed or splashed with a rusty or russet colored coating which materially detracts from its appearance. In very mild cases of injury fruit of a naturally good color may, it is said, practically overcome a slight russeting as the season develops. Such instances have been reported in this State this year. In more severe cases the apple has been stunted in growth and has suffered malformation, while the russeted surface may be greatly roughened, corrugated, or show pustule or teat-like formations. In very severe cases the skin may crack and exhibit V-shaped clefts in the flesh of the fruit (Fig. 50).

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* Mr. F. C. Stewart also reports spotting and yellowing of leaves following the use of an arsenical without bordeaux. "Two Unusual Troubles of Apple Foliage." New York Agric. Exp. Sta. (Geneva). Bulletin 220, Part II, p. 226.

Woodworth and Colby also ascribe leaf yellowing and early leaf fall to injury from Paris green. California Agric. Expt. Sta. Bulletin 126, p. 11. (1899).

BORDEAUX Injury; Literature and Comment.

The toxic action of copper compounds on plants has been a fertile field of investigation for botanists and plant pathologists at home and abroad, but the most recent important contributions to the literature of bordeaux injury are those of Prof. U. P. Hedrick, New York,* Prof. C. S. Crandall, Illinois,** and Dr. B. H. A. Groth, New Jersey.***

Hedrick's extended investigations and experiments developed the following points:

Spray injury is prevalent in all sections of the world where bordeaux mixture is used.

Excess of lime is not a preventitive, nor improperly made bordeaux the sole cause of injury.

Injury increases proportionally with the amount of copper sulphate used.

Wet weather following applications is a favorable condition for the production of injury.

Yellowing and leaf fall are dependent upon the amount of injury.

Different species vary in susceptibility to injury; the peach, apricot and Japanese plum being most readily affected, the common plum, quince and apple showing more resistance.

Varieties within the above groups vary in susceptibility to injury.†

Somewhat similar injuries occur on trees not sprayed with bordeaux, and are ascribed to factors of frost, fungi, arsenicals and the lens or "burning glass" action of drops of water on the fruit in intense sunlight.

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* Hedrick, U. P. "Bordeaux Injury". New York Agric. Expt. Sta. (Geneva), Bulletin 287 (1907).

** Crandall, C. S. "Bordeaux Mixture". Illinois Agric. Expt. Sta. Bulletin 135 (1909).

*** Groth, B. H. A. "Contribution to the Study of Bordeaux Injury on Peaches." New Jersey Agric. Expt. Sta. Bulletin 232 (1910).

† NOTE.—Attention is called to Hedrick's classification of apple varieties in relation to their susceptibility to spray injury which is given on pp. 346-349, of Bulletin 185 of the Maine Station.

Changes in the chemical nature of bordeaux are produced by weather conditions and by atmospheric moisture in particular.

The injurious action of bordeaux is ascribed to the solvent action of the cell sap and of meteoric waters following spraying, upon the copper hydroxide of the mixture. The copper thus left in solution is the toxic agent.

No great importance is attached by Hedrick to the nature of the lime (air slaked or freshly slaked), used in making the mixture as a factor in producing injury.

Crandall, after a series of carefully controlled experiments covering a number of seasons, arrived at the following conclusions:

Air slaked lime in bordeaux gives more injurious results than when freshly slaked lime is used.

Equal and full dilution of the two ingredients gives least injury.

Excess of lime is advantageous only as a subsequent spray and not as an addition to the bordeaux.

Properly prepared bordeaux gives injury under unfavorable weather conditions; rain and dew are important assisting factors.

Small amounts of copper become soluble soon after the application of bordeaux, and this solvent action increases more rapidly with meteoric waters than with water artificially applied.

The physical condition of the leaves bears a relation to the amount of injury. Lesions produced by insects and fungi render foliage more susceptible to injury.

Recurrent leaf yellowing epidemics have no direct relation to weather conditions, and evidence of bordeaux as the sole cause of yellowing is not established. Copper sulphate solutions, however, when injected directly into trees produce yellowing, the degree of injury depending on the strength of the solution.

Groth's work was confined to the peach after some preliminary work which included the apple and the plum. His experiments, conducted both in the field and under control conditions under glass, led him to a theory of spray injury involving, among the chemical and meteorological factors previously recognized, a physiological one. He finds:

Bordeaux injury is independent of the density of the application.

Copper is the toxic agent.

Apples are more resistant to injury than peaches.

The factors necessary to the production of injury appear to be water on the leaves, high atmospheric humidity, shade and an excess of plant respiration over carbon dioxide assimilation.

His theory is, that under proper conditions of minimum light intensity, the carbon dioxide of respiration exceeds that of assimilation and escapes through the stomata where, dissolving in water on the leaves, it brings the copper of the bordeaux mixture into solution. Such solvent copper enters the leaves by diffusion through the stomata and causes death of the cells.

The solvent action of plant secretions upon bordeaux mixture mentioned by Hedrick as a possible causative agent in bordeaux injury of the apple is doubtless offered on the strength of analogous experiments of Schander* with bordeaux in its relation to Fuchsia and Oenothera and also with Phaseolus multiflorus.

This work is cited by both Hedrick and Crandall. Schander ascribes all bordeaux injury to the action of secretory organs upon the copper hydroxide. Crandall, in commenting on this, points to the fact that no proof of the solvent action of secretory organs upon bordeaux has been demonstrated in the case of the apple. The possibilities, as Crandall notes, are in favor of a combination of many of the factors heretofore regarded as solvents of the copper in the mixture; the physiological factor recently submitted by Groth appears to be a vital one in arranging experiments where the conditions of control shall be well assured.

Leaf injury has in all cases, so far as known, been ascribed to the entrance of copper in solution into the leaf tissues. How this toxic agent comes in contact with the tissues finally destroyed is a question regarding which there is a difference of opinion. One theory of inhibition and osmosis held by a group of prominent foreign investigators is opposed to the chemotactic theory of others.**

Crandall has rightly emphasized the necessity of isolating and determining, if possible, the group of factors now held responsible for injury under the general heading of atmospheric conditions, and Groth's experiments have been along this line. In addition, as Crandall again points out, the physical condition of the leaves as related to injury demands experiments to determine this point.

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* Schander, R. "Ueber die Physiologische Wirkung der Kupfervitriolkalkbrühe." Landwirtschaftliche Jahrbücher 33, pp. 517-584. (1904.)

** For a detailed account of these theories and the experiments on which they are based, see Crandall (*loc. cit.* pp. 228-232).

Clark* considers that the amount of injury done to a species is dependent upon the following conditions:

The specific susceptibility of the protoplasm of the plant to the toxic action of copper.

The solvent properties of the cell sap on the copper hydroxide.

The permeability of the epidermis or cuticle to the cell contents under favorable exosmotic conditions.

Weather conditions following spraying which provide conditions for exosmosis of a portion of the cell contents.

Obviously, if these are the necessary conditions, there is another important physiological factor to be considered. This is the nature of the cell content of the leaves, which will regulate the degree of permeability. Such cell contents will depend largely upon the conditions that affect the metabolism of the leaf. Nothing makes this appear more evident than the striking differences in the amount of injury produced under identical conditions on trees of varying degrees of thriftiness.

CHOICE OF INSECTICIDES.

The use of insecticides has not to date given rise to such serious problems. Insoluble arsenicals have been the common agents employed, usually combined with the fungicide solution. Paris green was the form of arsenic originally used and is still adhered to by some. Although effective, it has been very largely superseded by arsenate of lead which combines equal efficiency with increased adhesiveness and greater safety to foliage.

The tendency of arsenate of lead to undergo chemical change when combined with the fungicide, and the nature of such change when it does occur, are questions now before station chemists. Of late arsenite of lime has been recommended by

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* Clark, J. F. "On the Toxic Properties of Some Copper Compounds with Special Reference to Bordeaux Mixture." Botanical Gazette 33: pp. 26-48. (1902.)

Prof. J. P. Stewart* as a cheaper and chemically more stable form of arsenic to use. Stewart's data indicate a slower rate of decomposition of this material in combination with lime-sulphur solutions than either Paris green or arsenate of lead. Its adhesive properties appear to be less than the latter's. No field experiments are cited to support the recommendation. Experiments of the season just past have shown that arsenite of lime is less desirable than arsenate of lead.†

Whatever the differences of opinion regarding the actual method of injury, the fact accepted by all investigators in this field is that copper is the injurious element in bordeaux mixture. Recognizing this fact, an effort has been made in recent years to eliminate the copper containing solutions in spraying plants of proved susceptibility despite their recognized high fungicidal efficiency, and to find a satisfactory substitute.

Sulphur and Sulphur Compounds as Fungicides.

In this effort attention has chiefly been turned to solutions of sulphur in chemical combination.

Pure sulphur in powdered form has long had a place among fungicides. Flowers of sulphur has been used for the control of powdery mildew of the grape (*Uncinula necator* (Schw.) Burr.) and is effective in greenhouses against rose mildew (*Sphaerotheca pannosa* (Wallr.) Lév.). A lime-sulphur paste is also mentioned by Duggar‡ as a means of control of this greenhouse fungus.

"Curiously enough, however, as early as 1833, before the general use of fungicides. Dr. Wm. Kenrick§ recommended for mildew on grapes a mixture of sulphur (1½ pints), quicklime (a piece the size of the fist) and boiling water (2 gallons). This mixture, after cooling, was diluted with cold water and allowed to settle. The clear liquid was then drawn off and diluted to make a barrel full before using. In 1885 Wm. Saunders[*] also recommended for pear blight a self-boiled lime and sulphur wash consisting of 8 pounds sulphur and one-half bushel of lime with boiling water, the mixture to be applied as a whitewash with brushes, and for mildews he advised applications of the clear sulphur liquid drawn off from this wash and greatly diluted."[**] This was the forerunner of Mr. W. M. Scott's now well known "self boiled" lime sulphur preparations.

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* Stewart, J. P. "Concentrated Lime-Sulphur. Its Properties, Preparation and Use." Annual Rept. Pa. State College (1908-1909) Part II, pp. 292-293.

†Mr. L. Caesar of the Ontario Agricultural College reports severe injury in some cases this past season from the use of arsenite of lime. In general the results were markedly inferior to those obtained with lead arsenate.

‡Duggar, B. M. "Fungous Diseases of Plants" (1909), p. 90.

§The New American Orchardist (1833), p. 328.

In spraying peach trees in the Pacific Coast States with boiled lime sulphur solutions for the control of San José scale it was found that this insecticide also served in some way as a fungicide, in that a winter application acted successfully as a preventative of peach leaf curl (*Exoascus deformans* (Berk.) Fuckel) the following spring. Possibly it was this fact that furnished a hint of the availability of lime-sulphur solutions for other fungous parasites.

Experiments at the New York (Geneva) Station in 1902[†] developed the fact that lime-sulphur applied in early spring for the control of San José scale had an apparent fungicidal effect in controlling apple scab (*Venturia Pomi* (Fr.) Wint.) Later work at this station also took into account the fungicidal value of the early lime-sulphur application as a substitute for the first bordeaux-arsenical spraying.[‡] As this application was made before foliage developed it gave no indication of the value of the sulphur solutions for summer use. Summer spraying at a strength sufficient to control San José scale on Japan plums was injurious to the trees.

Experiments in making a lime-sulphur wash without boiling were reported without data as to trials.[§]

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[*] Report of the U. S. Commissioner of Agriculture, 1885, pp. 43-44.

[**] Scott, W. M. "Self Boiled Lime Sulphur Mixture as a Promising Fungicide." U. S. D. A., Bureau of Plant Industry Circular 1, (1908).

[†] Lowe, V. H. and Parrott, P. J., "San José Scale Investigations IV. Part 1." N. Y. Agric. Expt. Sta. Bul. 228 (1902), pp. 405-407.

[‡] Parrott, P. J., Beach, S. A. and Woodworth, H. O. "The Lime-Sulphur-Soda Wash for Orchard Treatment." N. Y. Agric. Expt. Sta., Bull. 247, (1904).

Parrott, P. J., Beach, S. A. and Sirrine, F. A. "Sulphur Washes for Orchard Treatment." N. Y. Agric. Expt. Sta. Bull. 262, (1905).

[§] Lowe, V. H. and Parrott, P. J. *loc. cit.* Part III.

PREVIOUS EXPERIMENTS WITH LIME-SULPHUR AS SUMMER SPRAYS.

Two forms of lime-sulphur sprays have been employed as fungicides since 1907—the self-cooked or so-called "self-boiled" preparation devised and first used by Mr. W. M. Scott of the Bureau of Plant Industry, U. S. D. A., and the boiled solution first tried as a summer spray by Prof. A. B. Cordley of the Oregon Experiment Station.* The results obtained have proved an incentive to further work along these lines by the Federal Department of Agriculture and station workers in several states where the fruit growing industry is of considerable importance.

Scott's work in 1907** carried on in Arkansas and Missouri, was a comparison of his self-boiled with the cooked lime-sulphur and with bordeaux in the control of bitter rot (*Glomerella rufomaculans* (Berk.) Spauld. and von Schrenk), apple blotch (*Phyllosticta solitaria,* E. & E.), peach brown rot (*Sclerotinia fructigena* (Pers.) Schroet.) and peach scab (*Cladosporium carpophilum,* Thüm). The self-boiled mixture was of the 15-10-50 formula.† Both cold and hot water were used in the making. The 5-3-50 formula was boiled for 45 minutes. Weather conditions were favorable for spraying, and 3 applications were made.

Results: Bitter rot, a serious trouble in southern apple regions, was successfully controlled by self-boiled lime-sulphur, as indicated in the following table.

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* NOTE.—The commercial lime-sulphur preparations do not differ in nature to any extent from the properly prepared home-boiled concentrated solution.

** Scott, W. M. *loc. cit.*

† NOTE.—In referring to the composition of lime-sulphur solutions in this bulletin, the first amount represents pounds of lime, the second pounds of sulphur, and the last gallons of water. For the dilutions of concentrates the first figure represents concentrate in gallons, the second water. For bordeaux mixture, copper sulphate in pounds is given first, lime in pounds next, and water in gallons last.

Table 1.

	Per cent Sound Fruit.	
	Ben Davis.	Givens.
Lime-sulphur self-boiled	90.96 to 92.72	96.90 to 99.02
Bordeaux	91.65 to 96.40	89.12 to 99.80
Unsprayed	9.50 to 19.08	37.79 to 60.66

Apple blotch on Ben Davis trees was satisfactorily controlled with the self-boiled spray without leaf injury. The boiled 5-3-50 solution gave considerable leaf scorch and some defoliation, but no injury followed the use of the self-boiled spray.

Apple leaf-spot was held in check and peach brown rot and peach scab were both well controlled by the self-boiled solution. No data were taken on the control of apple leaf spot (*Sphaeropsis malorum*, Pk.), but observations showed no infections after applications were begun. No experiments in controlling apple scab were made at this time. Concentrated lime-sulphur at 1-25 did no injury to apples, but no effective strength was found that was not harmful to peach trees.

Cordley* was the first to record the favorable results of using a concentrated boiled lime-sulphur. His first work was with a stock solution of home preparation showing a specific gravity of 1.27 (Beaumé 31°) and an analysis of 2.38 pounds of sulphur per gallon. This was used on apple, peach, pear, plum, prune, quince, grape, potato and celery. The results indicated that a dilution of 1-15 could be safely used on all of these plants except the peach. His experiment on Yellow Newtown apples for scab control yielded the following results.

Table 2.

	Per cent. Clean.	Per cent. Slightly Scabby.	Per cent. Badly Scabbed.	Per. cent. Spray Injury.
Unsprayed	19.9	28.7	51.3	0
Bordeaux, 3 applications.	49.1	35.4	15.5	31.9
Lime-sulphur 3 applications.	79.3	15.3	5.3	0

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* Cordley, A. B. "Lime-Sulphur Spray to Prevent Apple Scab." Better Fruit, Sept. 1908, p. 26.

A very great superiority of lime-sulphur over bordeaux in scab control is here shown on this one variety for that particular season. It is more valuable as an indication of lime-sulphur efficiency *per se* than as an index of its superiority over bordeaux as a fungicide.

In 1908,* using both kinds of lime-sulphur sprays and bordeaux on the same block of trees, these results were obtained.

Table 3.

	Per cent Clean.	Per cent. Slightly Scabby.	Per cent. Badly Scabbed.	Per cent. Spray Injury.
Unsprayed	15.1	17.1	67.1	0
Self-boiled Lime-sulphur 2 applications	50.0	16.5	33.3	0
Bordeaux 3-3-50. 2 applications	55.9	8.0	35.9	52.1
Boiled Lime-sulphur 2 applications	69.6	18.8	11.3	0

Here again we find a greater efficiency in scab control of boiled lime-sulphur over bordeaux.

Especially noteworthy is the high per cent of spray injury to fruit sprayed with bordeaux, and its entire absence on both lime-sulphur plots. This immunity was not shared by the foliage. The same dilution used without any bad effects in 1907 seriously injured the leaves in 1908. Cordley accounts for this by the difference in climatic conditions in these seasons. He would endow a greater resistance to injury to the foliage produced under the favorable conditions for growth that existed in 1907. In 1908 a greater precipitation and lower temperatures produced, according to his explanation, "a growth which was less vigorous, less hardy, more edematious and more susceptible to spray injury."**

In 1907 and 1908 Cordley and Cate*** tested bordeaux and concentrated lime-sulphur (home-boiled) on peaches for the control of peach fruit spot. Bordeaux of 5-6-50 and 3-6-50 strengths were used, and lime-sulphur (Beaumé 20°) at dilutions of 1-10, 1-18, 1-20, and 1-20 in successive applications. Bordeaux caused no injury in either season. In 1908 the 1-18 lime-sulphur of the second application resulted in very slight injury; the third at 1-20 inflicted noticeable damage. The fourth spraying at the same dilution had no further bad effect.

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* Cordley, A. B. "Lime-Sulphur Spray Preventive of Apple Scab." Better Fruit, April, 1909, pp. 33-35.

** Cordley, *loc. cit.* p. 35.

*** Cordley, A. B. and Cate, C. C. *loc. cit.*

In point of efficiency Bordeaux was pronounced slightly better on the basis of actual figures, with a difference in its favor so small as to leave open the question of its superiority.

In 1908 Mr. W. J. Morse* of this station attempted the control of apple scab with the self-boiled mixture of Scott's formula prepared with hot and with cold water, and bordeaux mixture, 3-3-50, making 3 applications. Several varieties failing to set fruit, the data were confined to 4 Fameuse trees in each plot. Scab-free fruit was as follows:

Table 4.

Treatment.	Bordeaux 3-3-50.	Self-boiled Hot Water.	Self-boiled Cold Water.	Unsprayed.
Per cent. clean fruit	50	33	16	1

No definite conclusions were drawn. Observations pointed to the prevalence of the disease in that season, as indicated also by the high per cent of scabby fruit. The increased strength of lime-sulphur prepared with hot water is indicated in its greater control compared with the cold water preparation.

Scott's experiments in 1908** were made in Georgia, Arkansas, Nebraska and Illinois and in New Hampshire in cooperation with the state experiment station. Results showed self-boiled 10-10-50 and bordeaux 2-4-50 to be equally effective in controlling cherry leaf spot (*Cylindrosporium padi*, Karst.) on Montmorency. Self-boiled 6-6-50 and commercial concentrates at 1-40 gave slightly less control. Attempts to determine the relative effectiveness of the sulphur sprays and bordeaux for apple scab on Winesap in Arkansas had to be abandoned early in the season, but estimates pointed to bordeaux, commercial lime-sulphur and self-boiled mixture as effective in the order named. In Nebraska the efficiency of commercial lime-sulphur for scab on the Winesap variety equalled 3-3-50 and 4-4-50 bordeaux. Dilutions of 1-25 produced slight leaf injury. Self-boiled mixture caused no damage, was less adhesive and less effective, preventing only the early infections. Bordeaux caused fruit russeting but no leaf injury.

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* Morse, W. J. "Notes on Plant Diseases, 1908. Maine Agric. Expt. Sta. Bull. 164, (1909).

**Scott, W. M. "Lime-Sulphur Mixtures for the Summer Spraying of Orchards". U. S. D. A. Bureau Plant Industry, Circular 27, (1909).

The experiments of Prof. Brooks* at New Hampshire, co-operating with the Bureau of Plant Industry, embraced, in addition to the home-prepared, commercial lime-sulphurs and bordeaux mixture, commercial bordeaux and a so-called unboiled lime-sulphur mixture; in preparing the latter the lime was slaked and diluted to half the final volume, and the sulphur added to the remaining 25 gallons. These were then united to form a purely mechanical mixture of 50 gallons. Trees used were McIntosh. Results were as follows.

Table 5.

	Times Sprayed.	Per cent. Badly Scabbed.	Per cent. Slightly Scabbed.	Per cent. Clean.
Self-boiled L. S. 15-10-50..	5	2.9	45.0	52.1
Lime and Sulphur Mixture, 9-6-50	5	10.2	57.8	32.0
Boiled L. S. 2-1-50........	5	3.8	42.6	53.6
Commercial L. S. 1-24....	5	0.9	9.4	89.7
Commercial L. S. 1-49....	5	1.3	16.5	82.2
Bordeaux 3-3-50..........	5	1.2	18.2	80.6
Commercial bordeaux....	5	1.7	24.5	73.8
Self-Boiled L. S. 15-10-50..	4	9.5	55.8	34.7
Lime and Sulphur Mixture, 9-6-50	4	7.1	46.4	46.5
Bordeaux 3-3-50.....	4	1.2	9.4	89.4
Bordeaux 4-4-50..........	4	2.7	5.6	91.7
Unsprayed................		21.9	45.2	32.9

The percentages here again indicate an efficiency of the self-boiled lime-sulphur considerably lower than the commercial or home-made concentrates. Bordeaux was most effective and commercial sulphur sprays were superior to the home made. The mechanical lime-sulphur mixture was highly inefficient.

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* Brooks, Chas. N. H. Expt. Sta. 19th and 20th Reports (1908). Report of Dept. of Botany, pp. 385-389.

No injury was effected by the sulphur sprays. "In fact while there was occasionally an apple on the bordeaux plots whose appearance had been damaged by spray, the apples on the lime-sulphur plots were smoother and apparently more waxy and more highly colored than on the check plots."*

Prof. R. K. Beattie** of the Washington State station in a comparative test of bordeaux and lime-sulphur on Jonathan and Ben Davis trees obtained the following data. The proportions of lime-sulphur indicated were obtained by diluting commercial concentrates to the desired strengths.

Table 6.

Spray.	Per cent. Clean Fruit.
Lime-sulphur ½-1-4	95
Lime-sulphur ½-1-5	93
Lime-sulphur ½-1-6	88
Lime-sulphur 1st and 2nd applications	89
Lime-sulphur 2nd and 3rd applications	94
Lime-sulphur all three applications	92
Lime-sulphur all sprayings	91
Bordeaux with vermorel nozzle	52
Bordeaux with bordeaux nozzle	40
Bordeaux made with milk of lime	48
Bordeaux made with lime water	39
Bordeaux all trees	44
Unsprayed	17

The last application, made just after the petals fell, was on a rainy day. No injury to fruit or foliage occurred with the lime-sulphur sprays, but fruit russeting resulted from bordeaux; such fruit was classed as unmarketable and was not included in the above table.

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* Brooks, C. *loc. cit.*

** Beattie, R. K. "Lime-Sulphur Wash for Apple Scab." Western Fruit Grower. Jan. 1909, pp. 6-7.

At the Delaware station Prof. C. A. McCue* in 1908 sprayed several varieties of peaches with commercial and both home-made sulphur sprays, sulphur water and benzoate bordeaux. He did not consider his results the basis for definite conclusions, and merely pointed out the promising possibilities of the lime-sulphur sprays as fungicides for the peach. Benzoate bordeaux and sulphur water he declares unsafe, as well as undiluted lime-sulphur, irrespective of its time of boiling. Although controlling brown rot with the self-boiled spray, he could not obtain peaches free from a heavy coating of lime.

The season of 1909 witnessed an extension of experimental work along the lines in question. At the Michigan station Taft and Wilken** compared commercial and home-made concentrates on apples, pears, cherries and plums. At 1-25 the proprietary sprays caused foliage injury and had to be reduced to 1-40. Home-made concentrate of 12-15-50 formula reduced to one-fifth of that strength for summer use did practically no damage to foliage.

At Cornell University, Wallace's work was concerned with the control of peach leaf curl† and apple scab. One form of a commercial lime-sulphur solution was employed.

On peaches strengths of 1-9, 1-12, 1-15 and 1-20 were used. The per cent effectiveness was arrived at by choosing limbs with the eyes closed and counting the leaves thereon. Results are given in the following tables.‡

Table 7.

JACKSONVILLE ORCHARD, EAST SIDE, SPRAYED APRIL 9, 1909.

Treatment.	Number of Trees.	Limbs Selected.	Number of Diseased Leaves.	Per cent. of Diseased Leaves.
Unsprayed................	4	14	660	58.9
Niagara Lime-sulphur 1–9	6	22	18	0.9

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* McCue, C. A. "Spraying for Brown Rot of the Peach, 1908". Delaware Agric. Expt. Sta. Bull. 85, (1909).

** Taft, L. R. and Wilken, F. A. Mich. Agric. Expt. Sta. Special Bull. 48, (1909).

† Wallace, E. "First Report Niagara Sprayer Co. Fellowship on Peach Leaf Curl and Its Control." Cornell University 1909. See also Bull. 276 (1909) N. Y. (Cornell) Expt. Sta. by E. Wallace and H. H. Whetzel, which gives additional data obtained by practical growers.

‡ Adapted from original.

Table 8.

JACKSONVILLE ORCHARD, WEST SIDE, SPRAYED APRIL 12, 1909.

Treatment.	Number of Trees.	Limbs Selected.	Number of Diseased Leaves.	Per cent. of Diseased Leaves.
Unsprayed................	4	15	584	34.3
Niagara L. S. 1–12.........	4	26	106	4.1
Niagara L. S. 1–15.........	5	22	46	2.3
Niagara L. S. 1–20.........	5	30	204	6.1

Table 9.

ITHACA ORCHARD. SPRAYED APRIL 7, 1909.

Treatment.	Number of Trees.	Limbs Selected.	Number of Curled Leaves.	Per cent. of Curled Leaves.
Unsprayed................	4	28	920	41.3
Niagara Lime-sulphur 1–9	4	27	213	5.9
Niagara Lime-sulphur 1–15.....................	4	35	273	5.3
Bordeaux 3–3–50.........	5	37	427	8.3

According to this data, increase of control does not show an absolute relation to amount of dilution. Lime-sulphur is somewhat more effective than bordeaux. In the case of this disease, however, this is practically of no importance, since, according to Duggar,* it has been definitely established that for control spraying must be done before the buds open and later sprayings are of little importance when the early one has been made. Hence the question of leaf injury from bordeaux does not enter into this problem. The advantage of using one form of fungicide throughout the year is of course obvious, but the absolute superiority of lime-sulphur over bordeaux in controlling this disease remains to be established.

Wallace's work on the control of apple scab** brings out more points of interest. The same commercial concentrate was used as in the peach experiments with 2 pounds arsenate of lead to

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* *Loc. cit.* p. 182.

** Wallace, E. "Second Report Niagara Sprayer Co. Fellowship on Apple Scab." Cornell Univ. 1909.

50 gallons. The variety tested was Rhode Island Greening, with the following results.*

Table 10.

Treatment.	Number of Trees.	Number of Apples Counted.	Per cent. Sound.	Per cent. Russeted.	Per cent. Scabby.
Unsprayed..................	5	1,663	2.5	29.7	42.3
Lime-sulphur, 1-30 + lead arsenate....................	5	2,632	52.0	3.7	3.6
Bordeaux mixture + lead arsenate....................	6	2.332	9.9	82.2	3.0

Wallace also gives a table showing the effect of applications at different times. According to this, one spraying of lime-sulphur after the petals fall was superior to bordeaux used at that time or before the blossoms opened, both as to scab control or freedom from spray injury. Only one tree was used in each division of this experiment and the results must be considered with this fact in view. It is also proper to note that the other experiments involved a small number of trees per plot.

Prof. Bethune** reports the results of commercial lime-sulphur for controlling apple scab and pear scab (*Venturia Pyrina* (Aderh.) Snow apples received 3 applications at the usual times of 1-25, 1-40 and 1-40 respectively. The results gave 99 per cent of unaffected fruit. In one block where the second spraying was omitted 85 per cent was scab free. The first application caused slight tip burn of foliage but no fruit was russeted.

Flemish Beauty pears received 4 successive applications of 1-9, 1-25, 1-40 and 1-40, entirely controlling the fungus. The 1-25 strength caused slight leaf injury; 1-40 did no harm. Spraying with bordeaux proved less effective.

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* Adapted from original table.

** Bethune, C. J. S. Rept. Ontario Agric. College and Experimental Farm (1909), pp. 34-35.

Professors Melander and Beattie[*] as a result of their trials recommended for apple scab boiled lime-sulphur at ½-1-5, without further dilution. This is practically the concentrated stock solution, and is far too strong for eastern conditions according to experiments so far on record. Such strength, however, they report as very effective without causing serious leaf injury.

The experiments of Scott and Ayres[†] in 1909 consisted of a trial of the 8-8-50 self-boiled wash on peaches on a commercial scale, using it alone or with arsenate of lead, for controlling peach brown rot, scab and curculio. Very large numbers of trees were included in these trials and the results were in all cases markedly successful, the yield of marketable fruit being increased in some cases by one hundred per cent. In another case the yield of marketable fruit was 10 times that from the unsprayed plot. Reports are also made in this connection of the commercially successful use of this spray in peach orchards of from 15,000 to 35,000 trees. Spray injury resulting from its application was so very small in amount as to be considered negligible.

For apple scab in Arkansas, Virginia and Michigan Scott[‡] used 4 commercial concentrates of 31° to 33° Beaumé density, both kinds of home-prepared lime-sulphurs and bordeaux. These were tried alone and with arsenicals. The tests were made on 11 varieties in the several regions. The commercial sprays were used at dilutions ranging from 1½-50 to 2½-50, with arsenate of lead 2 pounds-50 or Paris green 6 ounces-50.

The results showed considerable differences, both in respect to foliage and fruit injury and scab control, the variations evidently depending largely upon the atmospheric conditions at spraying time and the varieties treated. Greater injury was obtained with Paris green than with lead arsenate. The commercial solutions used alone were more injurious to foliage than when combined with lead arsenate. 1½-50 appeared to be the maximum strength consistent with safety. Bordeaux was somewhat behind the boiled sprays in per cent efficiency, while the self-boiled mixture ranked last. The latter caused neither leaf nor fruit injury, while Bordeaux produced russeted fruit in some cases. Slight russeting of fruit is also reported where the stronger commercial sprays were used.

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[*] Melander, A. L. and Beattie, R. K. Wash. Agric. Expt. Sta. Pop. Bull. 28.

[†] Scott, W. M. and Ayres, T. W. "The Control of Peach Brown-Rot and Scab." U. S. D. A., Bureau Plant Industry Bull. 174 (1910).

[‡] Scott, W. M. "The Substitution of Lime-Sulphur Preparations for Bordeaux Mixture in the Treatment of Apple Diseases." U. S. D. A. Bureau of Plant Industry Circ. 54 (1910).

Mr. M. B. Waite* has recently reported the results of several new fungicide combinations for the apple. In these iron sulphate or calcium sulphate is combined with standard bordeaux mixture or one of the forms of lime-sulphur solutions. These have been compared with the standard bordeaux, neutral bordeaux, both kinds of lime-sulphur sprays and a combination of the boiled lime-sulphur with bordeaux; all of these used with lead arsenate.

Promising results are given for the first year's work. The noteworthy facts are the fruit russeting of at least one variety (Ben Davis) by all the copper containing fungicides; the apparent reduction of injury by the addition of sulphur compounds to bordeaux and the promising action of a combination of iron sulphate and self-boiled lime-sulphur.

Parrott and Schoene** have recently reported the results of a large number of cooperative experiments conducted in 1910 by practical apple growers in New York with the home-made lime-sulphur concentrates. These results are almost unanimously favorable to the use of the spray as a substitute for bordeaux. Slight leaf injury and fruit russeting are noted, but of a nature entirely negligible in view of the general superiority to bordeaux. But one case of severe injury was experienced. Of the 20 orchardists conducting this experiment on a practical basis 19 purpose using the sulphur sprays the coming season.

Wallace's work during the season just past enlarged considerably on his previous field work.† About 90 plots, embracing 5 varieties of apples, 4 varieties of peaches and 2 varieties of pears were included in the experiments. The sprays used were boiled lime-sulphur at several dilutions with and without arsenicals, self-boiled mixture, bordeaux mixture with lead arsenate, and the latter used alone.

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*Waite M. B. "Experiments on the Apple with Some New and Little-known Fungicides." U. S. D. A. Bureau Plant Industry Circ. 58, (1910).

**Parrott, P. J. and Schoene, W. J. "Experiments with the Home Made Concentrated Lime-Sulphur Solutions." N. Y. Agric. Expt. Sta. (Geneva). Bull. 330, (1911).

†Wallace, E. "Lime-Sulfur as a Summer Spray." N. Y. Agric. Expt. Sta. (Cornell). Bulletin 289, (1911).

The results reviewed as a whole again demonstrated an efficiency of the sulphur sprays equal to bordeaux in fungus control and reduction of injury to foliage and fruit. Some leaf injury was obtained, but serious defoliation occurred in but 2 cases—one when arsenite of lime was used with lime-sulphur, the other when lime-sulphur with lead arsenate was applied to peaches with the carbonic acid gas sprayer.

Russeting was noted on apples, but of a degree no greater or even less than that effected by the weather on unsprayed fruit.

Wallace regards foliage injury from lime-sulphur* as entirely distinct from that produced by bordeaux mixture, because of the differences in chemical constituents. He is also of the opinion that injury from the former is limited to short periods following the application of the spray, and that injuries appearing a considerable time after spraying may be ascribed to the arsenicals used. In other words, in bordeaux as applied the copper is in the insoluble (hydroxide) or harmless form and cannot cause injury until certain changes occur. In lime-sulphur solution on the other hand, the sulphur is applied in the soluble form, which is then many times more caustic than at any time after it has once dried.

Wallace also emphasizes the conditions of the leaf as affected by insects and fungi and the vigor of the trees as important factors related to the degree and amount of injury inflicted. The amount of spray applied, according as this is excessive or moderate, is also regarded as bearing on the amount of injury.

In connection with the above field experiments laboratory studies of the fungicidal properties of lime-sulphur alone and in combination were made.** Spores of peach brown rot, apple scab and apple canker were employed.

The results show that equal concentrations are not equally efficient for different fungi. Arsenate of lead appears to have some fungicidal value, both laboratory and field tests indicating increased efficiency of the sulphur sprays when lead arsenate is added.

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* Wallace, E. "Spray Injury Induced by Lime-Sulfur Preparations." N. Y. Agric. Expt. Sta. (Cornell), Bull. 288, (1911).

** Wallace, E., Blodgett, F. M. and Hesler, L. R. "Studies on the Fungicidal Value of Lime-Sulfur Preparations." N. Y. Agric. Expt. Sta. (Cornell). Bulletin 290 (1911.)

The effect of carbonic acid gas, used in a gas sprayer, is worthy of note. With lime-sulphur solutions alone the reaction of the gas was not of a nature to produce injurious results. Such reaction where lime-sulphur was used with lead arsenate did result in injury to peach foliage. The results obtained by Wallace do not warrant him in recommending the use of a gas sprayer in applying these materials when combinel.

The addition of lime to lime-sulphur solutions gave no conclusive results. Laboratory tests indicated increased fungicidal powers by the addition of iron sulphate to the lime-sulphur; the use of the two combined with lead arsenate was less effective than when the iron sulphate was omitted.

Experiments at Highmoor Farm, Maine Agricultural Experiment Station, 1910.

The increasing evidence of spray injury and the results of the preceding season in the orchards at Highmoor Farm made it desirable to test out the lime-sulphur sprays as substitutes for bordeaux mixture in this State.

The experiment aimed at determining the following points:

1. The comparative efficiency of the lime-sulphur sprays and bordeaux mixture as fungicides, especially for apple scab.

2. A comparison of these sprays in regard to possible injury to foliage and fruit on a variety especially susceptible to spray injury—the Ben Davis.

3. The effectiveness of arsenate of lead in combination with lime-sulphur solutions.

4. The relation of possible leaf and fruit injury to the combination of sulphur sprays with lead arsenate.

The experiments as originally planned included a study of arsenic in other forms combined with the sulphur sprays and a trial of the latter without arsenicals. The number and condition of trees available this season for such a study made it necessary to confine it to the points aforementioned. These cover the really important questions in the lime-sulphur problem. It is, after all, of very secondary importance whether or not lime-sulphur as a fungicide may be advantageously substituted in the orchard for bordeaux. The question of paramount importance is the determination of its relation and action in conjunction with a reliable insecticide. From the standpoint of general economy for the grower the only solution of the spraying problem will be a safe and effective insecticide-fungicide combination.

An orchard of 128 Ben Davis trees from 20 to 25 years old, of fairly uniform size and condition, and promising a moderate yield per tree, was divided into 12 plots. Plot 1 contained 9 trees. The remainder consisted of 12 each, excepting Plot 9 which contained 11.* The following table gives data of treatment.

Table 11.

Plot.	Treatment.	Manufactured by	Average Density Degrees Beaumé.	Amount used in 50 gals. water.	Amount lead arsenate in 50 gals. water.	
					First Application.	Second and third Applications.
1	Unsprayed ...					
2	Lime-sulphur	Niagara Sprayer Company......	34	1¼ gals...........	2 lbs.......	3 lbs.
3	Lime-sulphur	Bowker Insecticide Co........	34	1¼ gals.............	2 lbs.......	3 lbs.
4	Lime-sulphur	Sterling Chemical Co	31	1¼ gals.............	2 lbs.......	3 lbs.
5	Lime-sulphur	Grasselli Chemical Co	33	1¼ gals.............	2 lbs.......	3 lbs.
6	Lime-sulphur	Jas. A. Blanchard Company......	32	1¼ gals........	2 lbs.......	3 lbs.
7	"Sulfocide" ..	B. G. Pratt Co...	40	¼ gal*.............	2 lbs......	3 lbs.
8	Intensified Self Boiled Lime-sulphur.	Home made.....		10 lbs. lime........ 10. lbs. sulphur....	2 lbs.......	3 lbs.
9	Boiled Lime-sulphur.....	Home made	31	2½ lbs. lime 5 lbs. sulphur **	2 lbs.......	3 lbs.
10	Bordeaux mixture	Home made		4 lbs. copper sulphate. 4 lbs. lime	2 lbs.......	3 lbs.
11	Bordeaux mixture	Home made		3 lbs. copper sulphate. 3 lbs. lime	2 lbs.......	3 lbs.
12	Unsprayed ...					

* The third application of "Sulfocide" was $\frac{3}{16}$ gallon to 50 gallons water.

** Boiled with a constant volume of 10 gallons water and used at same dilution as commercial concentrates.

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* Two trees in Plot 12 were accidentally sprayed on one side in the second application and were omitted from the final count.

In making the self-boiled lime-sulphur, hot water was used and an attempt made to secure a large amount of sulphur in solution by making it in a small 10-gallon cask, conserving the heat by a covering during the process, and allowing it to stand for about 45 minutes before using. The lime was high grade and quick acting. Sulphur flour was used.*

The lime of the boiled concentrated spray was slaked with a thin paste made of the sulphur in hot water, more water being added up to a total volume of 10 gallons. This volume was kept constant while the solution boiled for one hour. After cooling and straining it showed a density indicated in the table and was used at the same dilution as the commercial solutions.

Arsenate of lead was not added in any case until the time of application.

TIME OF APPLICATION.

Owing to the nature of the experiment, a hand pump outfit was used. The applications, made with Mistry Jr. nozzles, were exceedingly careful and thorough, and occurred on the following dates:

1st. When fruit buds began to show pink, May 13 to 16.
2nd. After the petals fell, June 7 to 9.
3rd. July 15 to 18.

WEATHER CONDITIONS DURING AND FOLLOWING SPRAYING.

Weather conditions at the time of the first application were most favorable. The days were bright, mild and warm, and remained so for at least a week after spraying.

The second application was interrupted and followed by weather of the kind most favorable for the production of spray injury, according to previous experiences with bordeaux mixture. Showers interrupted and followed the spraying. The temperature and humidity changes were great and sudden. Cold, rainy periods were followed by bright, hot, humid ones. Unfortunately meteorological apparatus had not been installed at this time and the observations in this regard are of necessity general. Fair weather accompanied and followed the final application.

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* It should be noted that the above method of making this mixture is in reality not the "self boiled" preparation of Scott's recommendation, but an *intensified* modification, whereby more sulphur than Scott advises goes into solution. In making the self-boiled mixture the directions at the end of this bulletin should be followed.

RESULTS.

Effect on Foliage. No injury to foliage occurred between the first and second applications.

Observations made 2 to 15 days after the second application showed leaf injury on all the sprayed plots except that treated with self-boiled lime-sulphur. This injury appeared as light reddish-brown spots, in many cases greater in area than bordeaux spots, and frequently seen on the marginal portions of the leaf. As the season progressed these dead areas became darker in color and brittle. In many cases the spots were small and round, being comparable in size and shape to those found on bordeaux injured foliage. The number of such areas per leaf was, however, considerably less.

The degree of injury varied but little on the several sulphur plots. Plot 2 was slightly better than Plot 3 in respect to freedom from injury. In the latter division the injury appeared to be confined to the smaller, less developed leaves. Plots 4 and 5 were both slightly superior to 2, and Plot 6 ranked equally with the latter.

Of all the lime-sulphur sprays the home-boiled preparation showed the greatest amount of leaf injury, and this was more apparent after the third application. (Fig. 48.) The actual amount of damage was slight. A fair estimate would be 2 per cent, compared with one-half to one per cent from the commercial sprays. In all cases, however, the injury had no apparent later effect. Foliage and wood growth were unchecked, fruit developed well and the functions of the tree seemed unimpaired. Indeed, as the season progressed, close observation was needed to detect any foliage injury whatever. (Fig. 57.) The leaves remained notably green and vigorous and hung on until long after harvest.

The "Sulfocide" plot showed leaf scorching of the most severe kind shortly after the second application. Leaves were so badly burned that the affected tissues were crisped (Fig. 49). De-

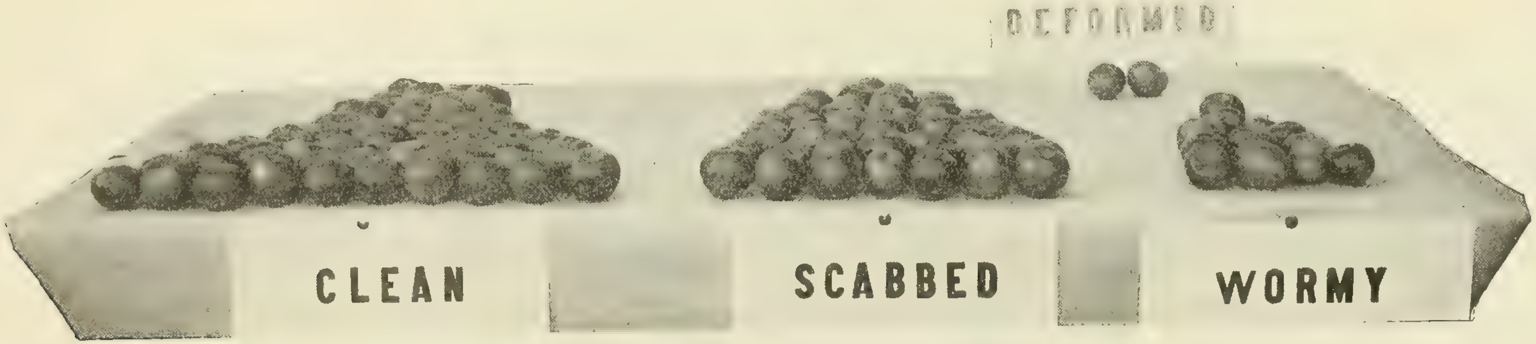

Fig. 37. Plat 1. Unsprayed, Clean 58.3%, Scabbed 41.6%, Wormy 13.7%, Deformed 1.9%.

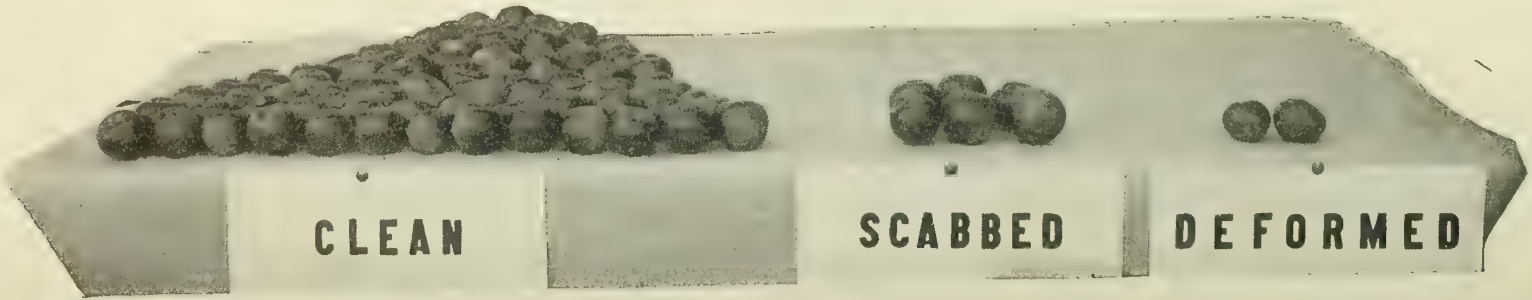

Fig. 38. Plat 2. Niagara Lime Sulphur plus Lead arsenate. Clean, 92.7%, Scabbed, 7.2%, Deformed 2.2%.

foliation was marked and from the general appearance of the plot at the close of the season it may be assumed that the vigor of the trees was considerably impaired (Fig. 56). Injury was increased by the final application, although this was at a greater dilution than the weakest strength recommended by the manufacturers.*

In comparison with the lime-sulphur sprays the bordeaux plots showed a markedly greater degree of leaf injury, estimated at 25 per cent. The characteristic leaf spotting was produced (Fig. 47), followed by a moderate amount of yellowing and leaf fall to a lesser degree. (Fig. 58.) No difference in effect on foliage was noted between the two strengths of bordeaux. The foliage suffered markedly in comparison with the lime-sulphur plots, after allowing for differences in appearance due to the color of the two sprays.

The adhesive quality of all the commercial solutions as well as the home-boiled concentrate was excellent on leaves and fruit, and compared well with bordeaux. The self-boiled mixture was inferior in this respect.

Effect on Fruit. Contrary to the experience of most investigators, all the plots showed injury to fruit.** Not even the self-boiled sulphur plot was free in this respect. The injury was of two kinds; one a russeting, roughening and pustulation of the skin, frequently accompanied by malformation and practically identical with the several degrees of bordeaux injury. The most severe injury on any of the lime-sulphur plots was somewhat less than the greatest injury from bordeaux (Fig. 51). No cracking or folding of the skin accompanied the former, and while russeting was quite common, it was of a nature in cases where malformation was absent to detract but slightly from the market value of the fruit.

The other form of spray injury, confined to fruit sprayed with sulphur solutions, occurred without exception at the calyx end, and will be designated as calyx injury.

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* The manufacturer's directions accompanying "Sulfocide" give Paris green as the insecticide to be used with it. Lead arsenate was used in this experiment to determine its action, as no field test of such combination seems to have been reported.

** NOTE.—It should be borne in mind that the Ben Davis is especially susceptible to spray injury, as compared with some other varieties.

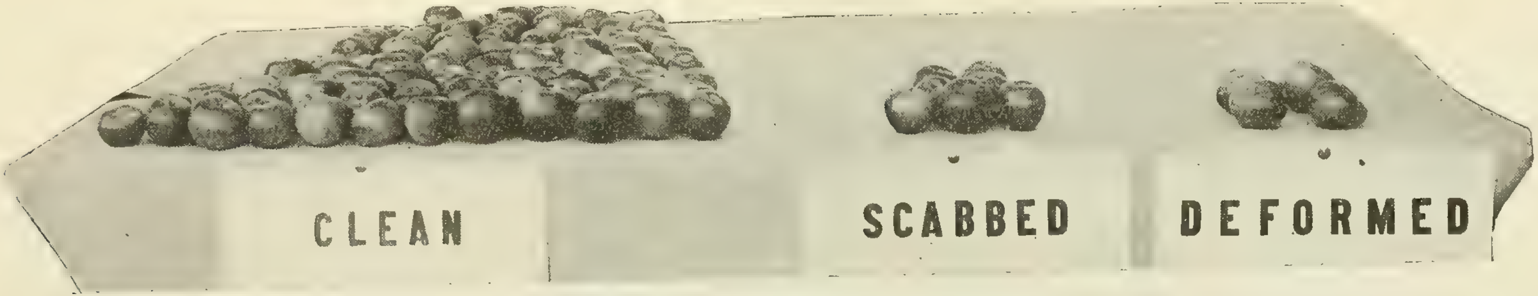

Fig. 39. Plat 3. Bowker Lime Sulphur plus Lead Arsenate. Clean 93.3%, Scabbed 6.6%, Deformed 3.5%.

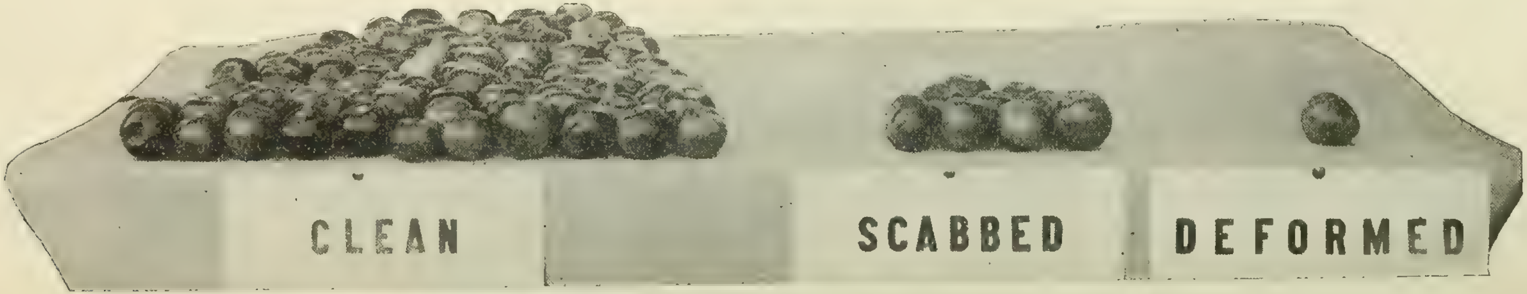

Fig. 40. Plat 6. Blanchard Lime Sulphur plus Lead Arsenate. Clean 91%, Scabbed 8.9%, Deformed 1.6%.

When this fruit was about one-third full size a dark brown discoloration of the tissues immediately surrounding the sepals was observed. This was on the average one centimeter in diameter and fairly regular and circular in outline. As the season advanced it did not increase noticeably in size, but became blacker. Such tissue was hard, tough and very resistant to pressure; an axial section showed that the injury was confined to the skin and to a very minute part of the sub-epidermal tissues. The macroscopic appearance of such tissues was in accord with the descriptions of "corked" tissues on other parts of bordeaux injured apples.

When this injury first became noticeable it was invariably accompanied by a bright carmine aureole upon the edge of the basin. This was the certain index of calyx injury on fruit hanging high enough on the tree to obscure the other indications. This aureole disappeared entirely with the growth of the fruit.

The blackened areas become somewhat depressed and frequently showed a tendency to separate and curl away slightly from the normal skin adjacent.

In rare cases this form of injury spread well into the basin, was irregular in outline and confined to one side of the calyx. Two examples of the more severe type of calyx injury are shown (Fig. 52).

Cases where the splitting of the skin at the edge of the injury gave opening for fungous infections resulted a little before harvest in the production of a very small amount of rot.

Injury from bordeaux mixture was of the nature indicated by the illustrations (Fig. 50) and tallied with the description of such injury previously given in this bulletin.

Both bordeaux and calyx injury were evidently inflicted by the second application of the spray. No further effects were noted after the final spraying.

The fruit on the "Sulfocide" plot suffered injury commensurate with that of the foliage, both in amount and degree. The burning appeared at the same time as the calyx injury already mentioned, but in this case the last application, although diluted beyond the specified recommendation, produced additional injury.

Here also the damage inflicted was chiefly at the calyx. It was vastly greater than that previously described, and more-

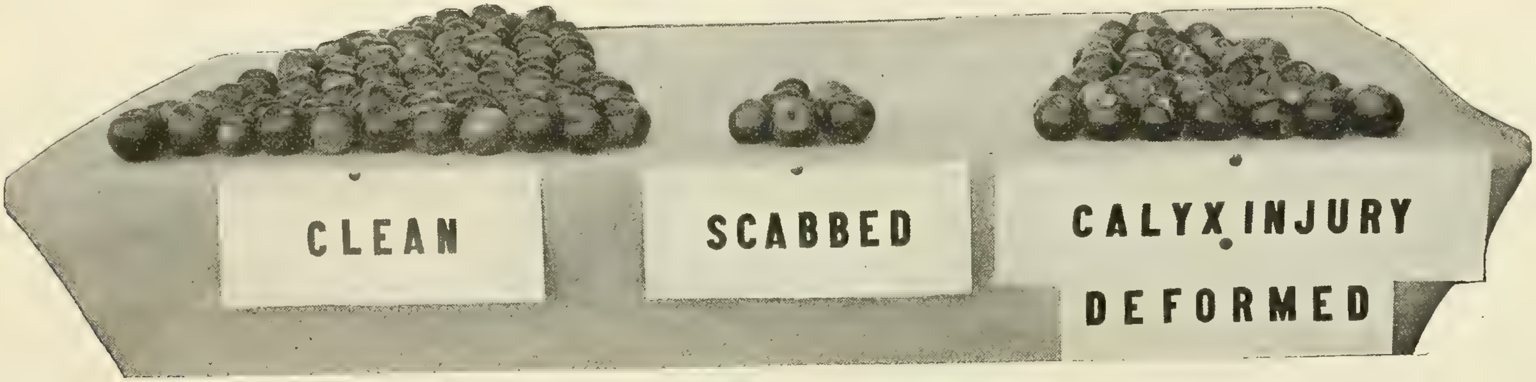

Fig. 41. Plat 7. "Sulfocide" plus Lead Arsenate, Clean 94.4%, Scabbed 5.5%, Deformed 44.3%.

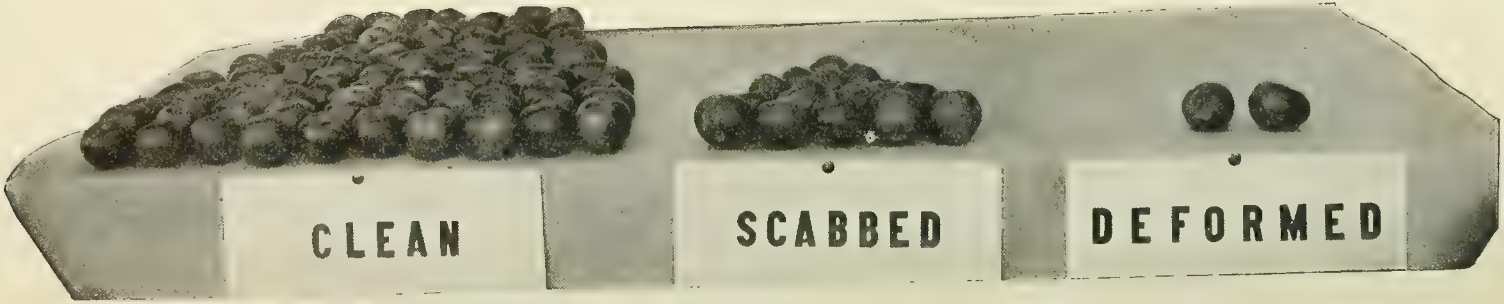

Fig. 42. Plat 8. Intensified Self Boiled Lime Sulphur plus Lead Arsenate. Clean 84.5%, Scabbed 15.4%, Deformed 2.1%.

over was not confined to the fruit basin or restricted to that part of the apple. The sides of the fruit were likewise affected and frequently deep clefts in the flesh occurred in conjunction with the burned skin. The injury when confined to the basin resulted in many cases in a marked shrinking and depression of that part. In addition, the fruit was stunted in growth and frequently misshapen. In color, texture and general characters the injury on these apples corresponded to that of calyx injury. It was, as may be seen, (Figs. 53 and 54) greater, and it also extended deeper into the sub-cuticular tissues. Rot of injured fruit at harvest was also greater on fruit from this plot.

In examining the fruit of the unsprayed plots we find evidence that must largely modify the conclusions to be drawn from this year's results. Fruit removed as completely as possible from the liability of catching spray from the other plots showed injury of the kind illustrated (Fig. 55). Aside from this, fruit not deformed showed a considerable amount of russeting, also of varying degree.

A comparison of fruit from the several plots as to general appearance was notably in favor of all the lime-sulphur sprays. The apples from such plots were larger, of better color and had an attractive waxy bloom. In this respect fruit from Plots 5, 6, 8 and 9 was especially noteworthy.

The "Sulfocide" plot produced smaller apples but on the average of still higher color. The fruit from the bordeaux plots was decidedly inferior in finish and color to any of the rest.

Effectiveness in Fungous Control.

The early part of the season was favorable for infection by scab and fruit spot (*Cylindrosporium Pomi.* Brooks), as indicated by the check plots and unsprayed trees in the vicinity of the orchards. A prolonged drought in June and July doubtless served as a check on late infections.

The leaves on the unsprayed trees were nevertheless considerably affected by scab, infection being estimated at 70 per cent, of which 50 per cent was severe.

The self-boiled lime-sulphur showed least fungous control of any spray used. Here the per cent of foliage infection was

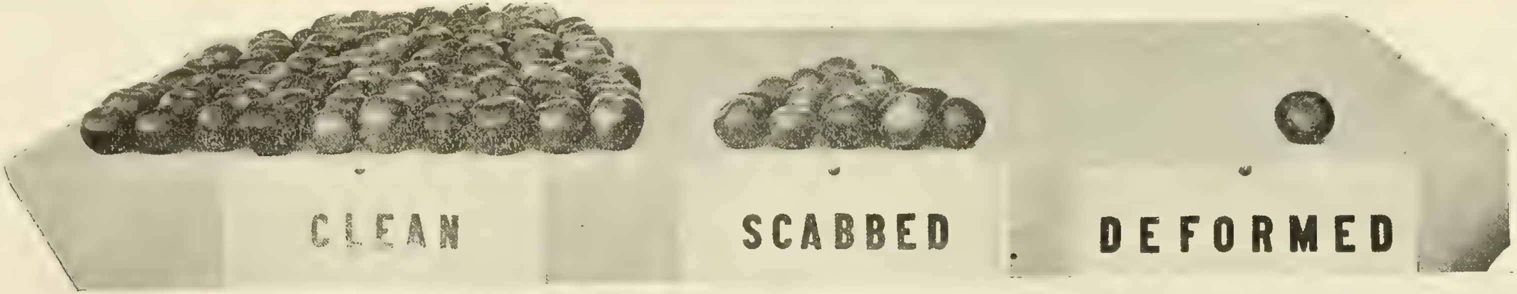

Fig. 43. Plat 9. Home Boiled Lime Sulphur plus Lead Arsenate. Clean, 85.2%, Scabbed 14.7%, Deformed 1.3%.

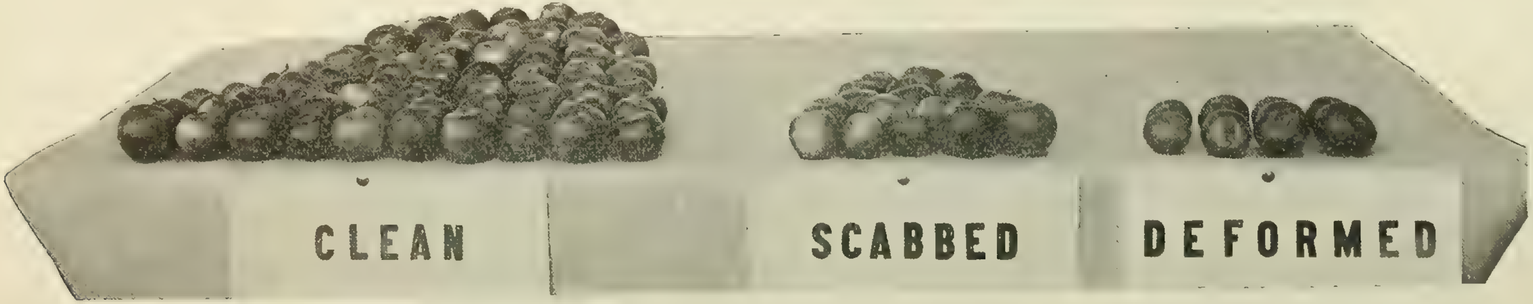

Fig. 44. Plat 10. Bordeaux Mixture 4-4-50 plus Lead Arsenate. Clean, 83.2%, Scabbed 16.7%, Deformed 6.7%.

estimated at 50 per cent, but none of it was of a degree severe enough to materially affect the functions of the tree.

In the other divisions control, so far as careful observations showed, was excellent and practically equal. The foliage was not entirely free from the fungus, but the infections did not become sufficiently established to do any evident damage. Such scabby foliage averaged from 4 to 8 per cent on the different plots.

In estimating the efficiency of control on the fruit, scab alone was considered. No gradations of scabby fruit were made; the resulting data therefore do not show the amount of fruit which was very slightly affected. This in practically all cases was more than 50 per cent of the scabby fruit of all sprayed plots, and should be taken into consideration.

Effectiveness of Lead Arsenate.

The results obtained indicate an almost perfect control of insects affected by arsenicals. The unsprayed plots were thoroughly infested during the season by codling moth (*Carpocapsa pomonella*, L.), yellow-necked caterpillar (*Datana ministra*), tussock moth (*Hemerocampa leucostigma*) and fall web worm (*Hyphantria cunea*). The last was extremely prevalent in Maine this season, and the check rows and unsprayed trees in the neighborhood were covered with the caterpillars. Not only leaves but fruit as well were attacked by them in Plot 1.

On the other hand, practically no trace of any of the aforementioned pests could be found on any of the sprayed plots. The cigar-case bearer (*Coleophora fletcherella*) and bud moth (*Tmetocera ocellana*) were present in all the orchards in the spring; the first spraying was not early enough to check the work of either insect, and some injury was done by the latter.

It should be noted that almost every fruit classed as wormy was in the case of the sprayed plots injured by the plum curculio (*Conotrachelus nenuphar*) and not by codling moth. The control of the latter pest was therefore practically absolute.

Russeted fruit as such was not included in the following data, as this was common to checks and sprayed trees alike, but severe deformity with russeting is given as an index of the amount of severe injury incurred. No distinction has been made between picked fruit and windfalls, as nearly all the fruit hung on the trees until a few days before picking time, when a quantity of fruit dropped during a wind storm. The windfalls were prevented from rolling by a deep cover crop, and no difficulty was found in assigning the dropped fruit to its respective plot.

Table 12.

Plot	Treatment.	Density Degrees Beaumé.	Number of Apples.	Per cent. without scab.	Per cent. Scabby.*	Per cent. Deformed.	Per cent. Calyx Injury.	Per cent. Wormy.
1	Check, Unsprayed		3,102	58.34	41.65	1.96		13.79
2	Niagara Lime-sulphur.........	34	7,736	92.70	7.29	2.22	1.75	0.63
3	Bowker Lime-sulphur.........	34	5,040	93.33	6.66	3.57	1.07	1.54
4	Sterling Lime-sulphur........	31	7,765	89.96	10.03	1.37	0.06	0.81
5	Grasselli Lime-sulphur.........	33	9,563	88.53	11.46	1.81	3.21	0.53
6	Blanchard Lime-sulphur.........	32	7,699	91.08	8.91	1.64	0.61	1.02
7	Pratt "Sulfocide"	40	3,660	94.42	5.57	44.39**		0.16
8	Intensified Self-boiled Lime-sulphur.........		3,181	84.59	15.40	2.13	1.03	1.03
9	Boiled Lime-sulphur............	31	6,551	85.25	14.74	1.31	0.09	1.23
10	Bordeaux 4-4-50..		7,185	83.29	16.70	6.77		1.51
11	Bordeaux 3-3-50..		5,215	85.96	14.03	5.79		1.97
12	Check, Unsprayed		6,092	59.24	40.75	2.47		7.33

* On sprayed plots 50 per cent. of respective amounts so slightly scabbed as to have fair market value.
** Deformity and calyx injury sufficiently coincident to combine in one count.

DISCUSSION OF RESULTS.

Examination of the above data shows a small balance of scab control in favor of the lime-sulphur sprays as against bordeaux mixture. The "Sulfocide" plot shows the highest degree of scab control, but the points to be discussed later do not incline one favorably towards its use, at least with arsenate of lead.

In general the chief significance of the foregoing table is the demonstration of the high fungicidal efficiency of the lime-sulphur sprays. The per cent variations are all within the range of experimental error, and their use in making comparisons between individual plots cannot serve as the basis for warranted conclusions.

Neither of the home-made sulphur sprays were quite as effective as the commercial concentrates. On the basis of former experiments, some reduction in fungus control was to be expected in the case of the self-boiled lime-sulphur. The conclusion, however, that home-made lime-sulphur concentrate is inferior to the commercial sprays, must not be drawn from one year's results, especially in view of the many experiments already cited, pointing to the contrary. We believe that this falling off, compared with the commercial solutions, may be partly accounted for by the greater foliage density of the trees of this plot. It is reasonable to suppose that with equal care in application, such increase of leaves, especially towards the center of the tree, would not only make control of the fungus more difficult, but the greater shade and reduced aeration would render propagation easier. The same explanation, although to lesser degree, may hold for Plots 10 and 11. Plots 9 to 12 inclusive consisted of somewhat larger and denser trees which had not been quite so heavily thinned in the pruning of the preceding winter. In general, however, we may consider this year's data confirm the consensus of results obtained elsewhere as to the practical efficiency of lime-sulphur sprays in the control of apple scab and other fungi.

Injury to Foliage and Fruit.

We have already seen that the lime-sulphur sprays proved immeasurably superior to bordeaux in their effect on foliage, and this under seasonal conditions at spraying time that put all materials used to the most severe test. On the question of injury to fruit, caution is needed in drawing conclusions. This is obvious when we consider the per cent of deformed fruit on both unsprayed plots (Table 12) and note its appearance (Fig. 55). These amounts run sufficiently close to the per cents indicated for the lime-sulphur sprays to warrant the assumption that the unknown agencies classed as weather conditions were this year responsible for much of the damage on the sprayed trees. Whatever these natural agencies may be, they were this year widespread throughout the country, as shown by reports of injury to sprayed and unsprayed fruit.

We cannot, however, concur with the view taken by some workers in this field, who, on the basis of their results, do not credit lime-sulphur sprays with ability to produce fruit injury. We incline to the belief that positive results such as ours are more significant than those of a negative nature. The fact that spraying trees with lime-sulphur has resulted in no injury to fruit may mean no more than the absence of conditions necessary for producing it with the spray in question, or that in some cases it has been used on varieties not especially susceptible to spray injury.

A comparison of the injured apples from the check plots (Fig. 55) and those from the lime-sulphur plots (Fig. 51) brings out the point at issue. The unsprayed fruit shows a good amount of russeting and remarkable deformity. But laying the fact of deformity aside, we do not find on the unsprayed plots the very evident pustulation or "pimpling" of the russeeted surfaces so clearly evident on fruit from the lime-sulphur plots. This, be it noted (Fig. 51), is practically identical in appearance with a moderately severe case of bordeaux injury.

Injury from lime-sulphur has moreover been reported in other states. Parrott and Schoene* recognize the russeting of apples sprayed this season with lime-sulphur. Two of the cooperative experimenters report severe russeting, although less severe than where bordeaux was used. Others report such injury to lesser degrees, and in general always less than the damage caused by bordeaux mixture.

Prof. Cordley reports fruit injury of a nature similar to our experience. In experiments conducted by him in the Willamette Valley no injury could be obtained on fruit "without using the spray at a strength sufficient to seriously injure the foliage. * * * In the Hood River Valley, where we conducted certain experiments, entirely different results were obtained. No injury whatever to the fruit was produced by the opening, nor by the second application which was made after application, which was made at the time the blossom buds were the petals fell; but serious injury to the foliage and fruit did result from the third application, which was made between May 23 and May 28, and which was followed immediately by a few excessively hot days—so hot in fact that some sunscald of the fruit occurred in orchards which were not sprayed. The injury in question occurred in two forms. From 2 to 5 per cent of the fruit, principally upon the southwest side of the trees, suffered seriously from what appeared to be sunscald, but which was more abundant in orchards which were sprayed with lime-sulfur than in orchards which were sprayed with some other combination. There later developed upon a considerable portion of the fruit, which at the time showed no injury, a form of 'russeting' very similar to that caused by bordeaux. Just what the explanation of this injury is, I am not prepared at this time to say, but the evidence points strongly to the conclusion that we should warn fruit growers against the use of lime-sulfur, at least at the strength at which we have been using the solutions during very hot weather."*

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* Parrott, P. J. and Schoene, W. J. *loc. cit.*

Fruit russeting following the use of lime-sulphur on apples has also been reported in Ohio this past season.**

These results would seem to be somewhat in accord with those obtained in Maine. The weather conditions, however, were different, and the injured fruit in our experiment was not confined to any particular side of the tree. It was, moreover, found equally on trees of thin and dense foliage.

Neither does the fact that some fruit injury was found on the intensified self-boiled lime-sulphur plot prove said injury to be solely due to weather conditions, when we recall that the mixture in this case was made with a view to getting the maximum amount of sulphur into solution.

The injury produced by bordeaux shows that it was from 2 to 5 times as great. It was also more severe. In this respect the results of this year agree with those of preceding investigators as to the evident reduction of serious damage by the substitution of lime-sulphur for bordeaux mixture as summer sprays. We believe that further work along this line will continue to furnish evidence warranting the substitution of lime-sulphur for bordeaux as a fungicide for all fruits most susceptible to spray injury.

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* Cordley, A. B. In correspondence, Nov. 14, 1910.

** Selby, A. D. Ohio Agric. Expt. Sta. In correspondence.

We are furthermore of the opinion that when weather conditions are right for the production of spray injury, no spray material now known can be relied upon to counteract or avoid it; and this will be especially true when said conditions produce injury on unsprayed fruit, as in the past season. Indeed it is highly probable that the fruit injury obtained this year (if we disregard the one kind that was undoubtedly caused by the arsenical), was due to the application of a spray, irrespective of its composition. In other words, under the unusual conditions at spraying time, the addition of moisture may have increased the *degree* of injury which the natural agents alone were capable of inflicting. Future experiments may prove that satisfactory fungicidal effects may be secured with greater dilutions at reduced risk of injury.

Effectiveness of Lead Arsenate.

This point has already been fully discussed. The results corroborate those of experimenters previously mentioned regarding the entire efficiency with lime-sulphur sprays, irrespective of the chemical changes occurring when used together. The check plots indicate that insects destructive to fruit were not especially numerous. Codling moth, as previously noted, was perfectly controlled.

"Sulfocide" and Calyx Injury.

The fact that calyx injury was found on neither check nor bordeaux plots, together with the very severe injury of similar nature on Plot 7 inclines us to the belief that this was the result of a chemical change whereby the arsenic was set free in some form capable of causing the results. The injuries already described and more particularly those on Plot 7 bear a very striking resemblance to descriptions of a similar injury noted by Taylór at the Missouri Fruit Station on apples sprayed in a rainy season with bordeaux and Paris green. Between the second and third applications "apples were noted in the Paris green plot with blackened areas about their blossom ends. These blackened areas increased in size and became more conspicuous as the apples grew. By picking time some of the areas now shriveled had extended about the blossom end until it covered over a third of the surface of the fruit. In some cases the burned tissue at the end of the apple had dried and separated from the normal portion and fallen away, leaving the seeds exposed at the bottom of circular cup-like depressions. Some apples less seriously burned showed deeply depressed calyx basins."[*] Nearly one-fourth of the picked fruit from these trees treated with Paris green were reduced from first class, and many to cull grade from this cause. Trees treated with arsenate of lead developed one per cent of apples blackened at the blossom end. Rainy weather was held accountable for the intensity of the damage inflicted.

Paddock[**] also reports an attempt to control an alternaria rot on apples described by Longyear,[***] which affected the fruit at the calyx end. Paddock concluded that much of said alternaria injury was really due to spraying with improperly prepared arsenicals, and emphasizes the necessity when using arsenite of lime on Ben Davis and Gano of spraying during fair weather only.

Scott and Quaintance[†] noted injury to leaves and fruit of the peach produced by lead arsenate in their 1908 experiments. Mr. J. P. Stewart of the Pennsylvania Station has observed a similar burning of peaches following the use of bordeaux and lead arsenate.

Cordley has indicated the differences in chemical reaction between lime-sulphur and the two kinds of lead arsenates, netural and acid, showing that the amount of soluble arsenic in mixtures of the fungicide with the acid arsenate is 4 to 7 times greater than when the neutral kind is used.[‡]

These facts are significant in view of the aforementioned injuries of this season. It is unreasonable to ascribe to a common cause injuries so much alike as the russeting from lime-sulphur and bordeaux mixture and this other form of damage, so markedly different, so distinctly localized and entirely absent on trees sprayed with bordeaux and lead arsenate. Evidently the answer must be sought in the reactions of the arsenates and the sulphur sprays.*

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[*] Taylor, E. P. "Spraying Apples for Curculio and Codling Moth". Missouri State Fruit Sta. Bull. 21 (1909), p. 69.

[**] Paddock, W. Rept. of Field Horticulturist. Colo. Agric. Expt. Sta. Press Bull. 43 (1907).

[***] Longyear, B. O. "A New Apple Rot". Colo. Agric. Expt. Sta. Bull. 105 (1905).

[†] Scott, W. M. and Quaintance, A. L. "Control of the Brown-Rot and Plum Curculio on Peaches." U. S. D. A. Bureau of Ent. Circ. 120 (1910).

[‡] Cordley, A. B. "The Lime-Sulphur-Arsenate of Lead Mixture." Better Fruit, May, 1910, pp. 37-41.

Relations of Density of Concentrate to Injury.

The degree of injury to fruit and foliage varied only in a general way with the density of the concentrates. Allowing for the factor of experimental error, the results are in accord with the present practice of increasing the dilution with the density.

CONCLUSIONS.

The experiment here recorded is the result of the first season's work and should be regarded as preliminary rather than the basis for final conclusions. In general the data presented show that lime-sulphur preparations may be efficiently used as summer sprays, and that with weather conditions liable to produce spray injury lime-sulphur does less damage than bordeaux mixture both qualitatively and quantitatively.

Further data are needed regarding variation in the effect of sulphur sprays on different varieties. Other questions are those concerning the minimum effective dilution and the action of different arsenicals in combination with them.

Arsenate of lead proved as effective with lime-sulphur as with bordeaux mixture. The use of a neutral lead arsenate is recommended in order to reduce any tendency to arsenical injury.

"Sulfocide" with lead arsenate gave unfavorable results on foliage and fruit. Its use with Paris green was not attempted. Favorable results have in some cases been reported by growers when used with the latter arsenical.

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* NOTE.—This is indicated by tests made by the chemists of this station. "Sulfocide" and an acid arsenate of lead used in the orchard experiments were mixed in the dilutions used in spraying, and allowed to stand. At the end of half an hour 100 cubic centimeters of the mixture after filtering showed 94 milligrams of soluble arsenious oxide. After standing for three days an equal volume yielded 104 milligrams, largely in the form of sodium arsenate.

The same test was made with the lead arsenate and one of the commercial lime-sulphur concentrates. Practically no arsenic was found in solution. Nevertheless the calyx injury on the commercial lime-sulphur plots must be ascribed to a reaction between the concentrate and the arsenate.

Unusual conditions favorable to the production of injury were prevalent this season. It is believed that future work with more dilute solutions will furnish still better reasons for the use of lime-sulphur as an orchard fungicide. The many experiments referred to, as well as the favorable reports of practical orchardists throughout the country, warrant Maine fruit growers in giving the new sprays a thorough trial. Aside from the experimental plots, this Station purposes using home boiled lime-sulphur of 31° to 34° Beaumé density at a 1-40 dilution on all its orchards.

The additional advantage of the sulphur sprays lies in their combined insecticidal and fungicidal powers. The same stock solution used to control fungous diseases in summer is successful at greater strength as an insecticide for sucking insects against which arsenicals are ineffective. Such strengths must be applied when the tree is not in leaf.

HOME MADE VS. COMMERCIAL LIME SULPHUR.

Commercial lime-sulphur preparations now on the market are not superior to concentrated home made stock solutions when these are properly made and stored. The former are, moreover, considerably more expensive. At present prices of material the home made concentrate can be made at a cost of one-third to one-fourth that of an equal volume of a commercial solution if the materials are bought in quantity. This does not include the original outlay for a cooker and barrels for storage. The commercial preparation is a convenience, requiring nothing but a knowledge of its density before diluting. The home made concentrate can be made at any time and if properly barreled and kept from freezing can be stored indefinitely. Home made lime-sulphur can also at present be made cheaper than the home-prepared bordeaux mixture, so far as cost of ingredients are concerned. The choice on grounds of economy is, therefore, merely between the expenditure of money or time and labor.

DIRECTIONS FOR MAKING LIME-SULPHUR SOLUTIONS.

The materials necessary for making these sprays are a good stone lime, free from grit or dirt, testing not less than 90 per cent calcium oxide and not more than 5 per cent magnesium oxide, and sulphur. Sulphur may be in the form of flowers of sulphur or sulphur flour.

Self-Boiled Lime-Sulphur.[*]

Use 10 pounds sulphur and 10 pounds of good stone lime to 50 gallons of water.[**] These quantities may be increased to any desired amount provided the proportions are maintained.

"Place the lime in a barrel and pour on enough water (about 3 gallons to 20 pounds) to start it slaking and to keep the sulphur off the bottom of the barrel. Then add the sulphur which should be worked through a sieve to break up the lumps and finally enough water to slake the lime into a paste. Considerable stirring is necessary to prevent caking on the bottom. After the violent boiling which accompanies the slaking of the lime is over the mixture should be diluted ready for spraying, or at least enough cold water added to stop the cooking. Five to 15 minutes are required, according to whether the lime is quick acting or sluggish. The intense heat seems to break up the particles of sulphur into about the physical condition of precipitated sulphur and the violent boiling makes a good mechanical mixture of the lime and sulphur. Only a small percentage of the sulphur—enough to improve the adhesiveness of the mixture—goes into solution, but if the hot mass is allowed to stand as a thick paste the sulphur continues to unite with the lime and at the end of 30 to 40 minutes enough of the reddish liquid is produced to burn peach foliage and even apple foliage in some cases. * * *

The mixture should be strained through a sieve of 20 meshes to the inch in order to remove the coarse particles of lime, but all the sulphur should be worked through the strainer.

The amount of water required to make the best mixture depends largely upon the lime. Some grades of lime respond quickly and take a large quantity of water, while others heat up slowly and are easily 'drowned' if too much water is added at once. Hot water may be used to good advantage in preparing the mixture with sluggish lime, but with quick-acting lime hot water is not necessary and is more likely to bring too much of the sulphur into solution. If desired the mixture may be kept for a week or more without deterioration, but should be thoroughly stirred before using."

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[*] Adapted from the several publications of W. M. Scott, Bureau of Plant Industry, U. S. D. A.

[**] An 8-8-50 formula is recommended by Scott in his latest report on peaches. 10-10-50 is doubtless none too strong for the apple.

In applying the self-boiled mixture the spray pump should be equipped with a good agitator, as the mixture settles to the bottom of the tank. In order to be evenly applied it must be well agitated.

It is to be noted that this mixture has been found less effective for apple scab than the boiled preparation.

Home Boiled Concentrated Lime-Sulphur.

Sulphur	110 pounds.
Lime, best grade	55 pounds.

Water sufficient to make 60 gallons.

"Slake the lime, mix the sulphur into a thin paste with a little water, add it to the lime, add sufficient water to make 60 gallons, bring to a boil and boil vigorously for 30 to 45 minutes. The sediment is then allowed to settle, after which the clear dark amber-colored liquid is drawn off and may be stored in casks for future use."*

In making this solution a large iron kettle or cooker of some sort is necessary. A stock feed cooker of large capacity will answer. Fig. 45 shows a satisfactory form which can be had of Montgomery Ward & Co., Chicago, Ill.; The Wagner Manufacturing Co., Sydney, Ohio; Farmers' Supply Co., Philadelphia, Pa.; or R. B. Dunning & Co., Bangor, Maine. The solution can also be made with the use of direct steam, and this means has been frequently employed when large quantities of the material are made.

DILUTING CONCENTRATED SOLUTIONS FOR USE.

With our present knowledge, the strength of lime-sulphur to use depends upon its density. This may be determined by a

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*Cordley, A. B. "Insecticides and Fungicides." Oregon Agric. Expt. Sta. Bull. 108 (1910).

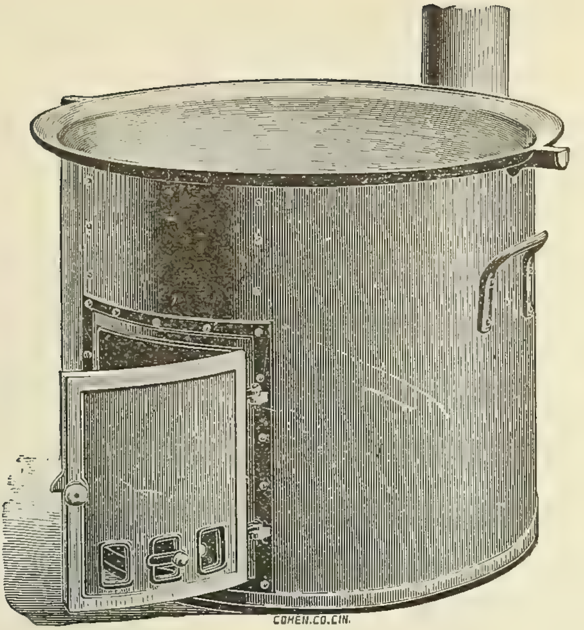
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Fig. 45. Lime Sulphur Cooker.

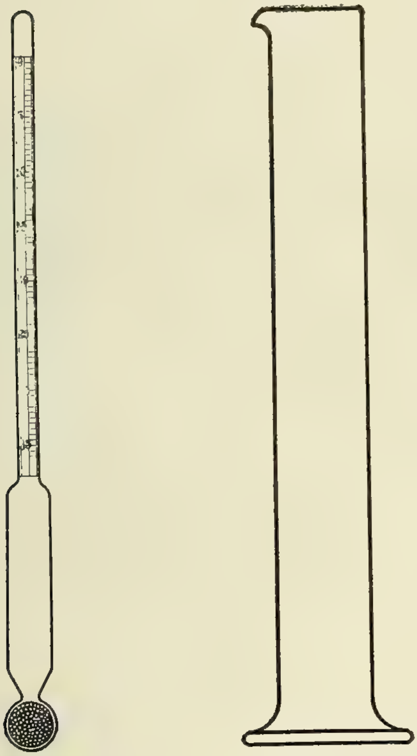

Fig. 46. Hydrometer and Cylinder for Testing Lime-Sulphur Densities.

cheap and simple instrument called the hydrometer. This consists of a hollow glass tube, its lower end terminating in a weighted bulb (Fig. 46). Placing this in a liquid, it sinks until the liquid displaced equals its own weight. In light solutions, therefore, it will sink deeper than in heavy or dense ones. The gradations to be read are marked on the scale on the neck of the instrument and are in degrees Beaumé or in terms of specific gravity. Some instruments give both scales. The Beaumé is the one most generally used.

These instruments cost about $1.00 and may be had of the Bausch & Lomb Optical Co., Rochester, N. Y., or other dealers in scientific apparatus. They are absolutely necessary for the proper use of lime-sulphur solutions. The contents of several casks from one manufacturer may vary in density, and experiments have shown that home boiled solutions will differ considerably in this respect even when the same amount of material and time of cooking are employed.

The solutions should be tested at a temperature of about 60 degrees, Fahrenheit. Density should never be determined when the solution is hot.

The following is a table of dilutions.*

Table 13.

Hydrometer Reading. Degrees Beaumé.	Number of gallons water for one gallon concentrated solution.	
	Winter Strength (Insecticide)	Summer Strength (Fungicide)
32	12	30
31	11	29
30	10	28
29	9½	27
28	9	26
27	8½	25
26	8	24
25	7½	23
24	7	22
33	6½	21
22	6	20

*Cordley's figures.

It will be noted that the dilution at 32 degrees Beaumé is stronger than that used in the Maine experiments on the Ben Davis. A dilution of 1-40 for a concentrate testing about 32 degrees is recommended for trial in this state on the more susceptible varieties of apples.

The concentrate should always be tested for density at the time of using. It is also a good plan to mark the density of each barrel-full at the time it is made.

Arsenate of lead should not be added until the solutions are diluted and ready for use.

If the concentrated solutions are to be stored for some time before using, the barrels should be entirely filled to exclude air. If this is not feasible, or when a part has been withdrawn for use and the balance is to be held for a considerable time, it should be protected from the air with a thin coating of paraffin oil or other heavy oil. If made during the winter it should not be allowed to freeze.

TIME AND METHODS OF APPLICATION.

Successful results from spraying operations depend upon three factors: properly prepared mixtures, timeliness and thoroughness of application. Too much emphasis cannot be laid upon them. Failure to observe these conditions may be held accountable for the great majority of cases where spraying has not given the results desired.

For the proper preparation or dilution of spraying mixtures it is only necessary to follow the directions given. Guesswork or slipshod methods should not be tolerated. The formulæ which have been and are being derived are the results of experiment and experience. Improvements may be made in the future. These the progressive orchardist will learn by obtaining the station bulletins on the subject as they appear.

Timeliness of application demands merely a knowledge of the orchard enemies to be fought. These are described and means of control recommended in former publications of this station.* When the grower finds evidence of insect or fungous injury the cause of which he does not know, the necessary information can be obtained by sending specimens to the station. Timeliness means protection by prevention.

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* Morse, W. J. and Lewis, C. E. "Maine Apple Diseases," Bull. 185 of this Station.

Patch, E. M. and Johannsen, O. A. "Apple Tree Insects of Maine," Circular 383.

Thoroughness of application* is largely a matter of experience and until this is acquired the idea of thoroughness will be that of the man who does the work. The amount necessary for each tree will depend upon the density of the foliage and the way it has been kept open by proper pruning.

Three important factors to be kept in mind in applying sprays are the maintenance of a high pressure, the use of the most efficient types of nozzles and the constant agitation of the liquid.

A pressure of less than 100 pounds is not likely to produce the best results, and the insoluble nature of the insecticide in the liquid makes constant agitation necessary to keep the arsenical in suspension.

With 100 pounds pressure and the improved type of nozzle the proper spraying of a large tree is a matter of very short time. The nozzle should deliver with considerable carrying power a spray of fine mist in the form of a hollow cone. Under these conditions it will be found necessary to keep the spray rod constantly in motion in order not to drench any part of the tree.

Whether hand pumps or power machines are desirable depends upon the size of the orchard and its location. Engine power sprayers will be found most economical in large plantations where their use is practicable. In small orchards, or in large ones located on very steep, rough slopes, the hand pump with its small spray tank may be best adapted. The greatest disadvantage of the average barrel pump is the difficulty of maintaining the high pressure necessary for good work, although some of the improved hand machines may meet the requirements. In large orchards the hand pump, unless attached to a large spray tank, involves much loss of time due to the necessity of repeated filling.

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* See Maine Station Bulletin 185, p. 391.

SUMMARY.

Spray injury inflicted by properly prepared bordeaux mixture on fruit and foliage is primarily due to part of the materials composing it, and cannot be avoided by any known means when weather conditions following the spraying are favorable for injury production.

The lime-sulphur sprays in the course of many experiments have been found in the majority of cases to be satisfactory substitutes for bordeaux mixture in controlling fungous diseases in orchards.

Some injury to foliage has been incurred with the use of lime-sulphur sprays. Part of such injury has been due to the use of too concentrated solutions or to leaf injuries caused by insects and fungi before the spray was applied. In practically all cases where proper dilutions were used leaf injury on apple trees was so slight that it could be entirely neglected.

Results of many experiments show absence or reduction of fruit russeting with the use of lime-sulphur.

The experiments at this station point to the following conclusions:

The commercial lime-sulphur sprays were satisfactory as fungicides and were superior to bordeaux mixture in their effect on foliage and fruit.

The home boiled concentrate was also satisfactory. The intensified self-boiled lime-sulphur mixture was less effective and less adhesive than any of the sprays used.

Lead arsenate was entirely effective as an insecticide when combined with the sulphur sprays.

Foliage injury occurred on all sprayed plots; it was more severe where bordeaux mixture was used. Leaf injury on the lime-sulphur plots was small in amount and not lasting in its effects.

Injury to fruit was of two kinds. One was very evidently due to the arsenical used with the sulphur spray. The other form was similar to bordeaux injury, but less severe.

Unsprayed fruit suffered severe russeting and malformation, due probably to weather conditions.

Comparison of injured fruit from sprayed and unsprayed trees showed a greater degree of injury to the russeted surfaces on sprayed fruit. Such increase of injury may be due to the nature of the spray, or merely to the addition of moisture at a time when atmospheric conditions could increase the *degree* of an injury which they could inflict without such addition.

Injuries ascribed to arsenicals are undoubtedly due to changes taking place when lead arsenate is combined with the lime-sulphur solutions. A neutral lead arsenate is recommended to reduce the possibilities of injury. The amount of this injury was this season small, and from the reports of other work is not a common occurrence.

The use of "Sulfocide" with lead arsenate was decidedly injurious.

On the basis of other experiments, the use of a carbonic acid gas sprayer is not recommended in applying lime-sulphur with lead arsenate.

In conclusion we would encourage the trial of the lime-sulphur solutions, home made or commercial, as substitutes for bordeaux mixture, especially on varieties of apples where bordeaux injury has been noted. The general results of this season's experiment coincide with the many others reported in this bulletin regarding the effectiveness of lime-sulphur sprays as fungicides, and the reduction of injury to foliage and fruit. It should be remembered that the natural conditions that caused much damage on unsprayed fruit this past season are not of common occurrence, and still more favorable results may be looked for in the future.

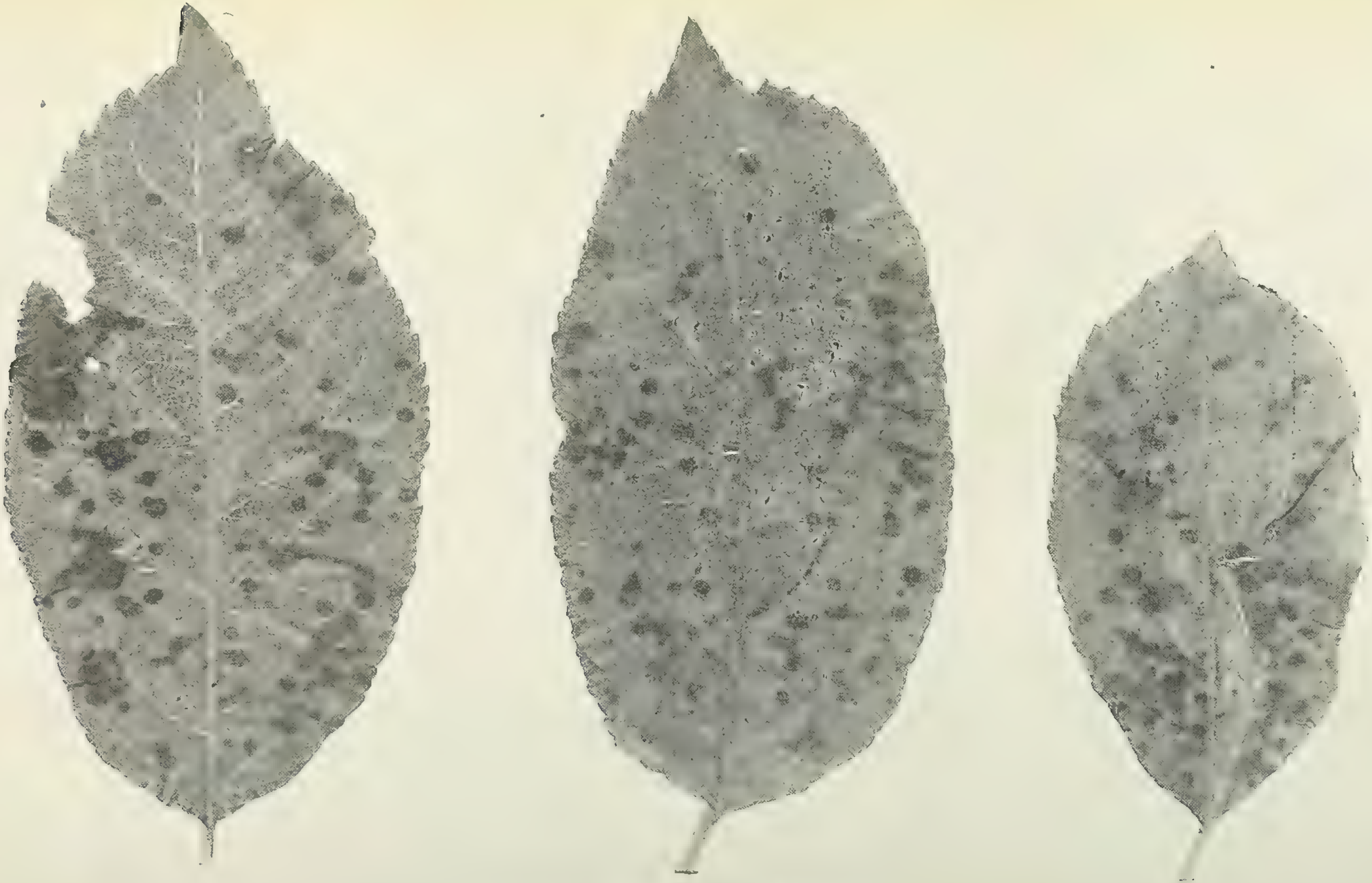

FIG. 47. Bordeaux Leaf Injury.

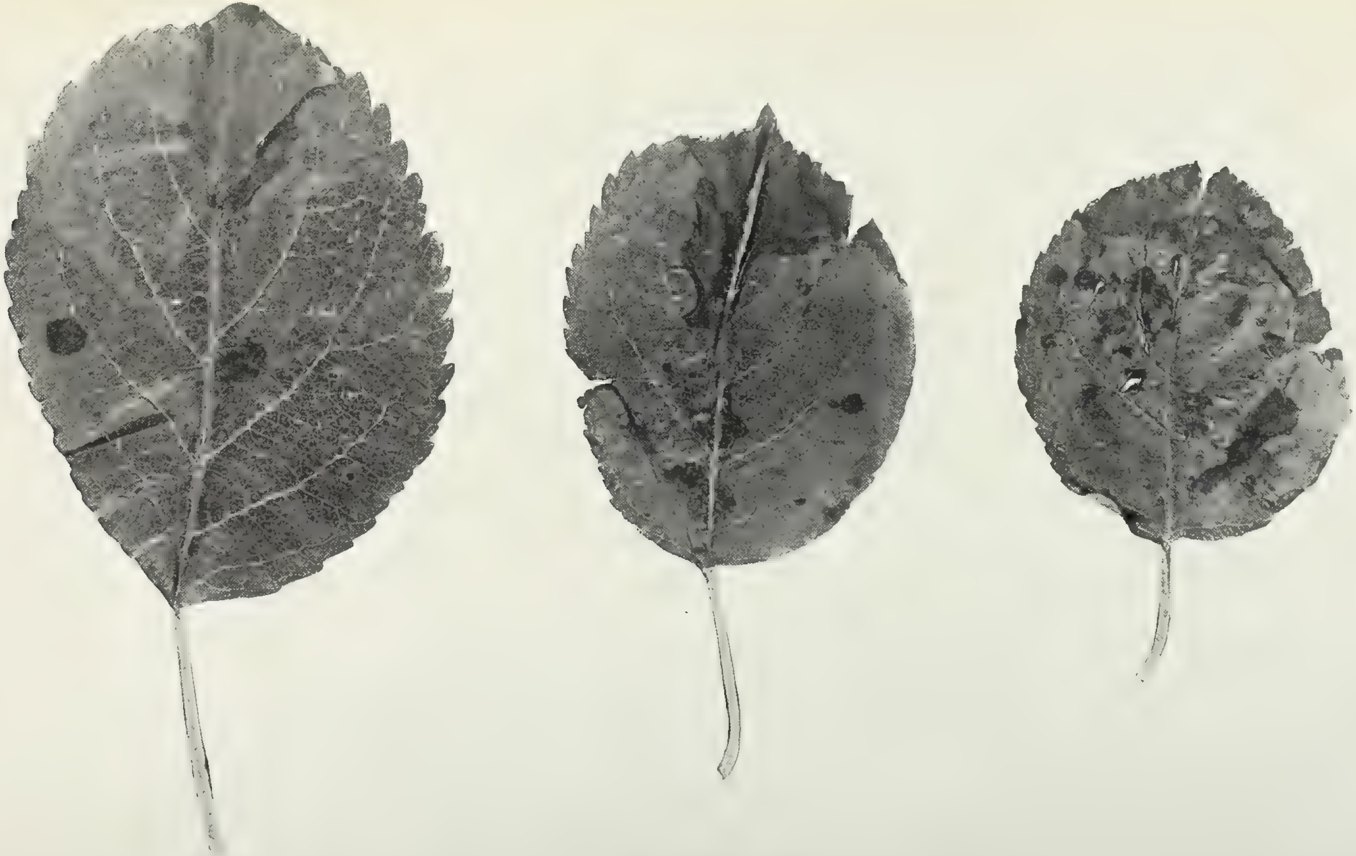

FIG. 48. Lime-Sulphur Leaf Injury.

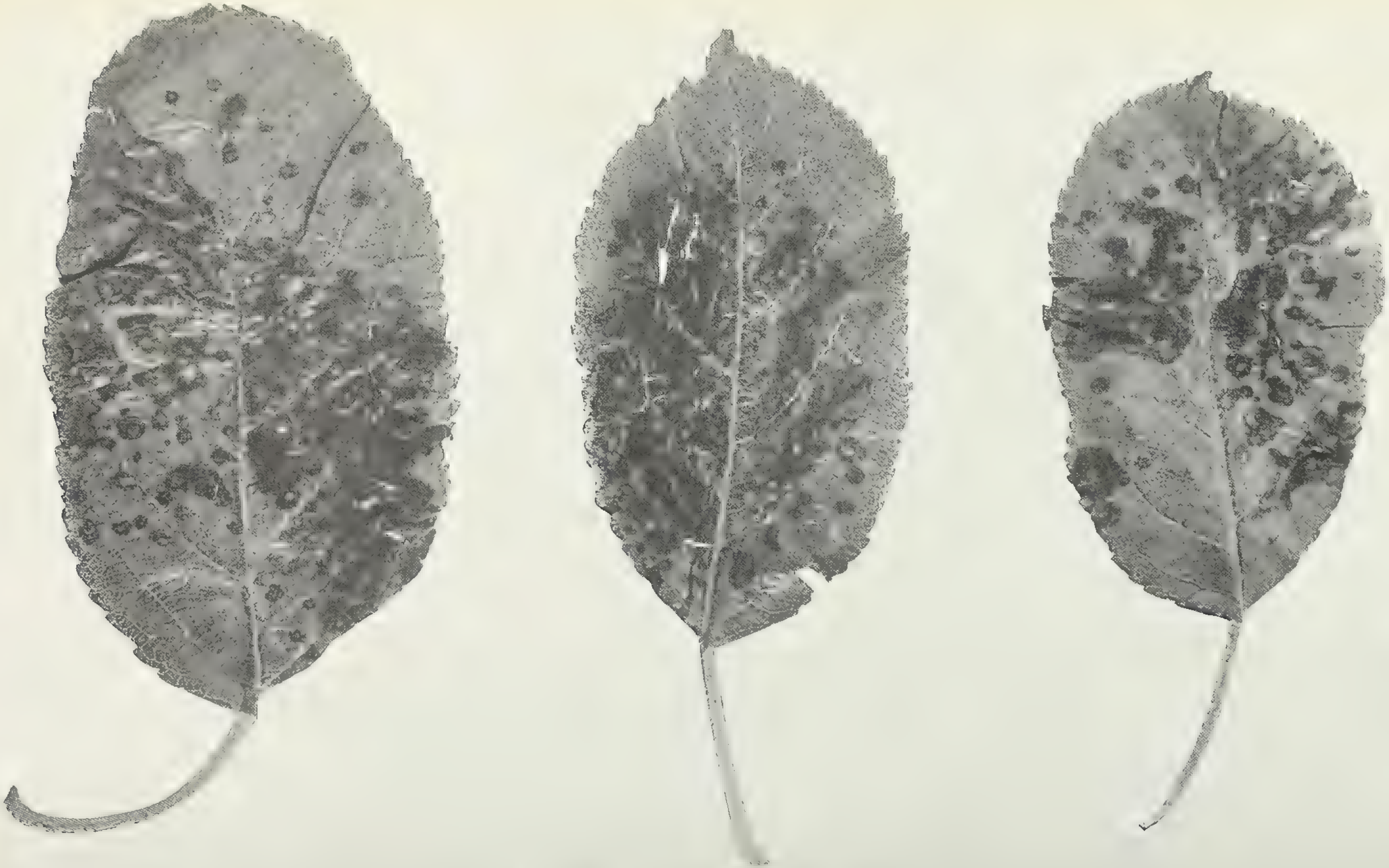

FIG. 49. "Sulfocide" Leaf Injury.

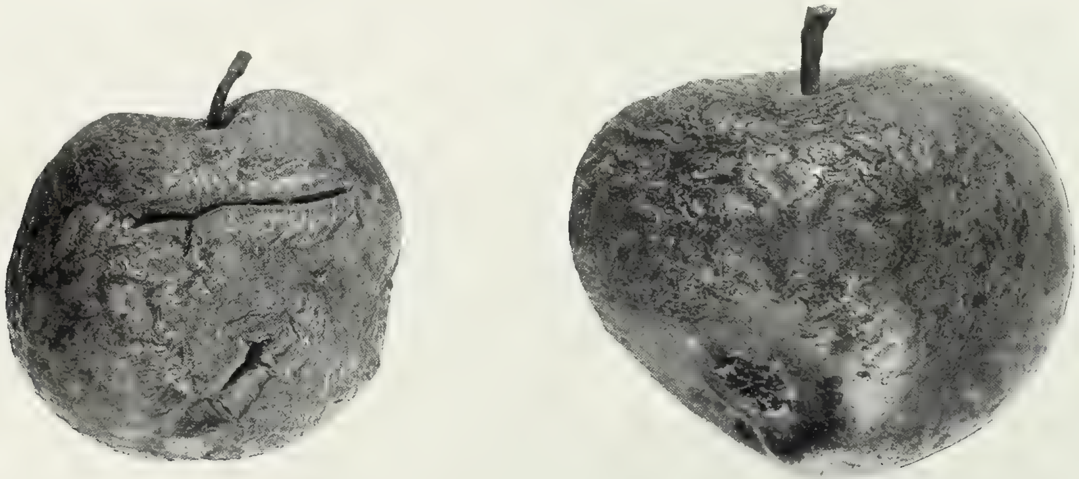

Fig. 50. Bordeaux Injury on Ben Davis

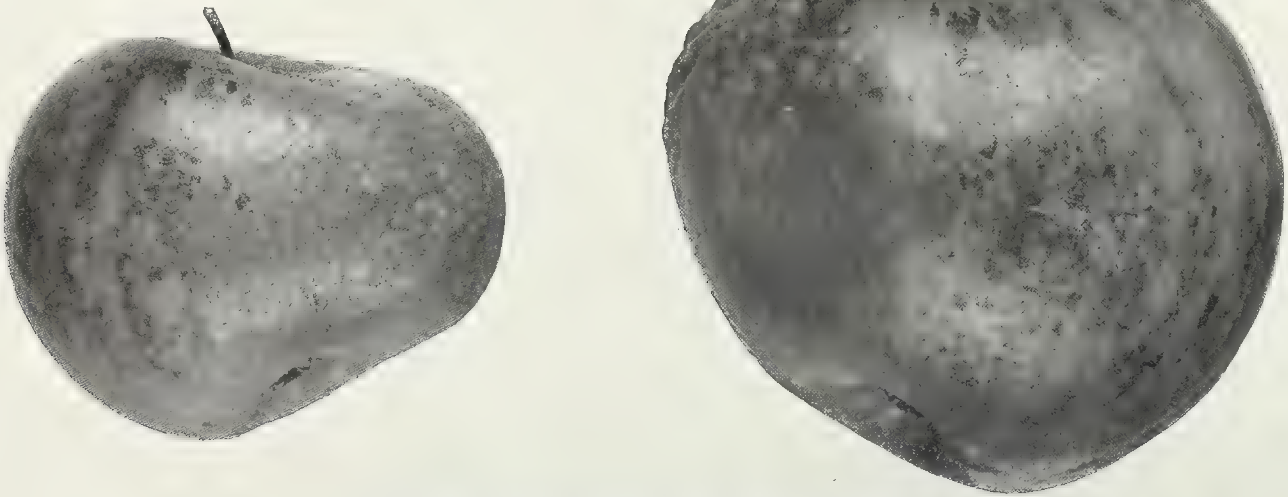

Fig. 51. Lime-Sulphur Injury on Ben Davis

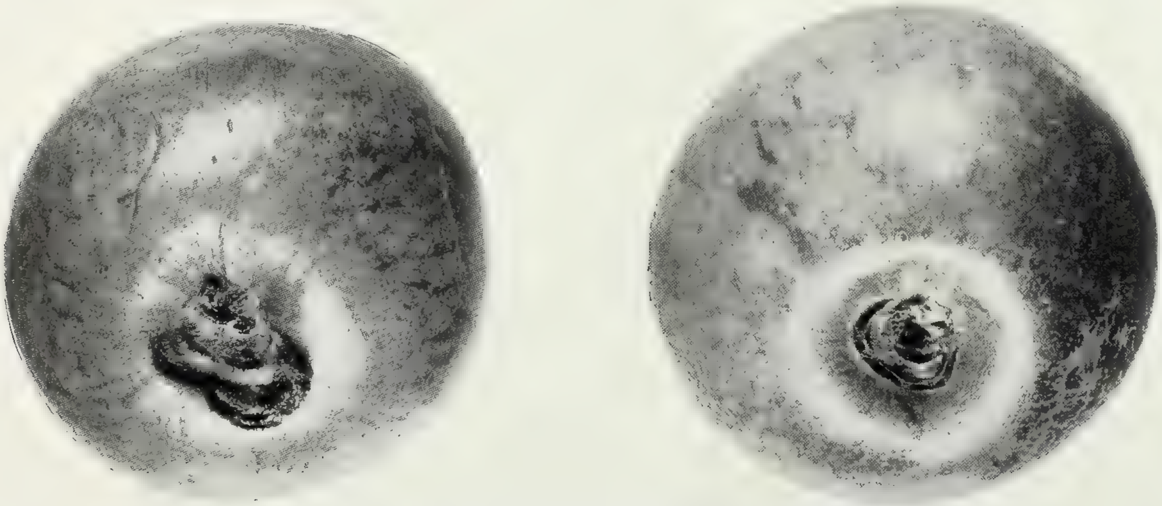

Fig. 52. Calyx Injury (Lime-Sulphur Plus Lead Arsenate)

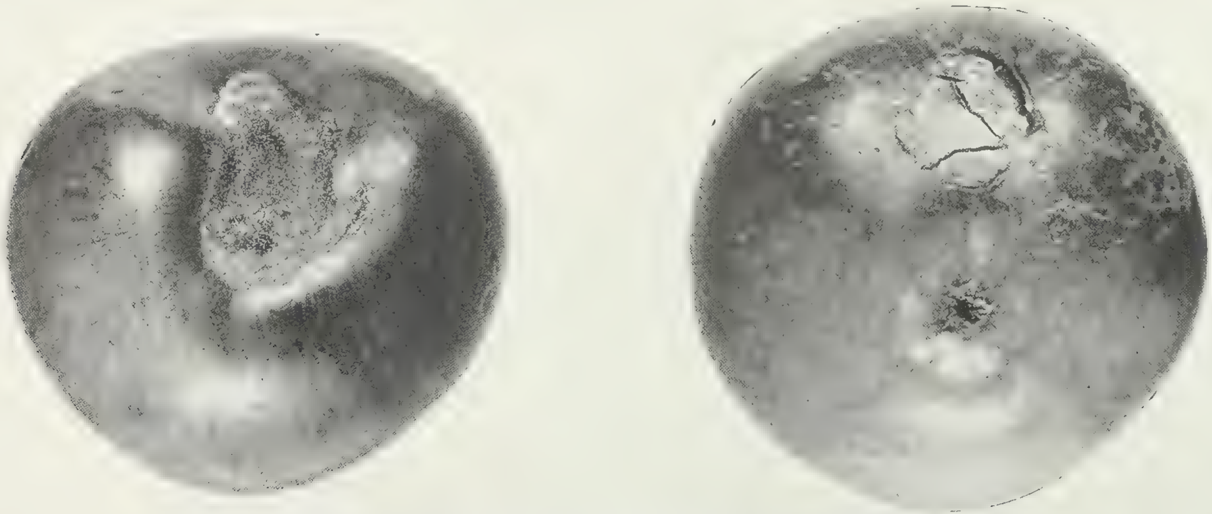

Fig. 53. Injury from "Sulfocide" Plus Lead Arsenate

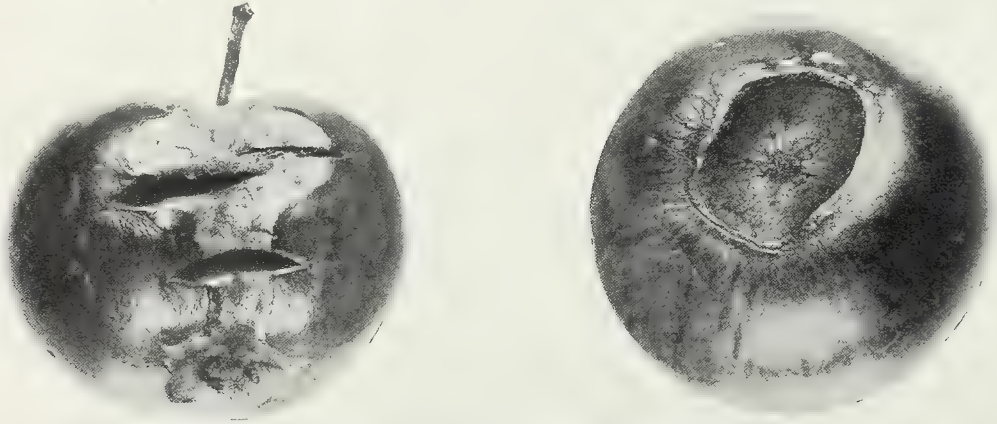

Fig. 54. Injury from "Sulfocide" Plus Lead Arsenate

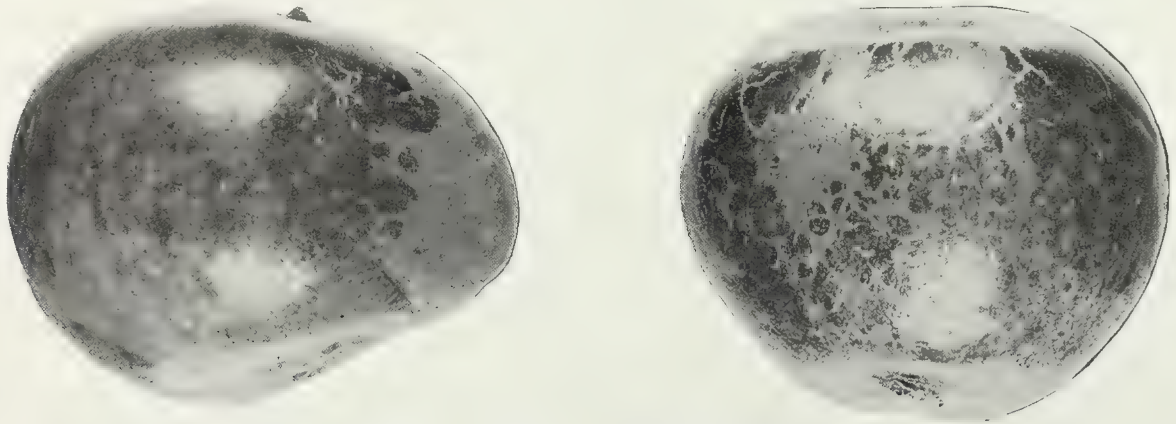

Fig. 55. Injury on Unsprayed Fruit

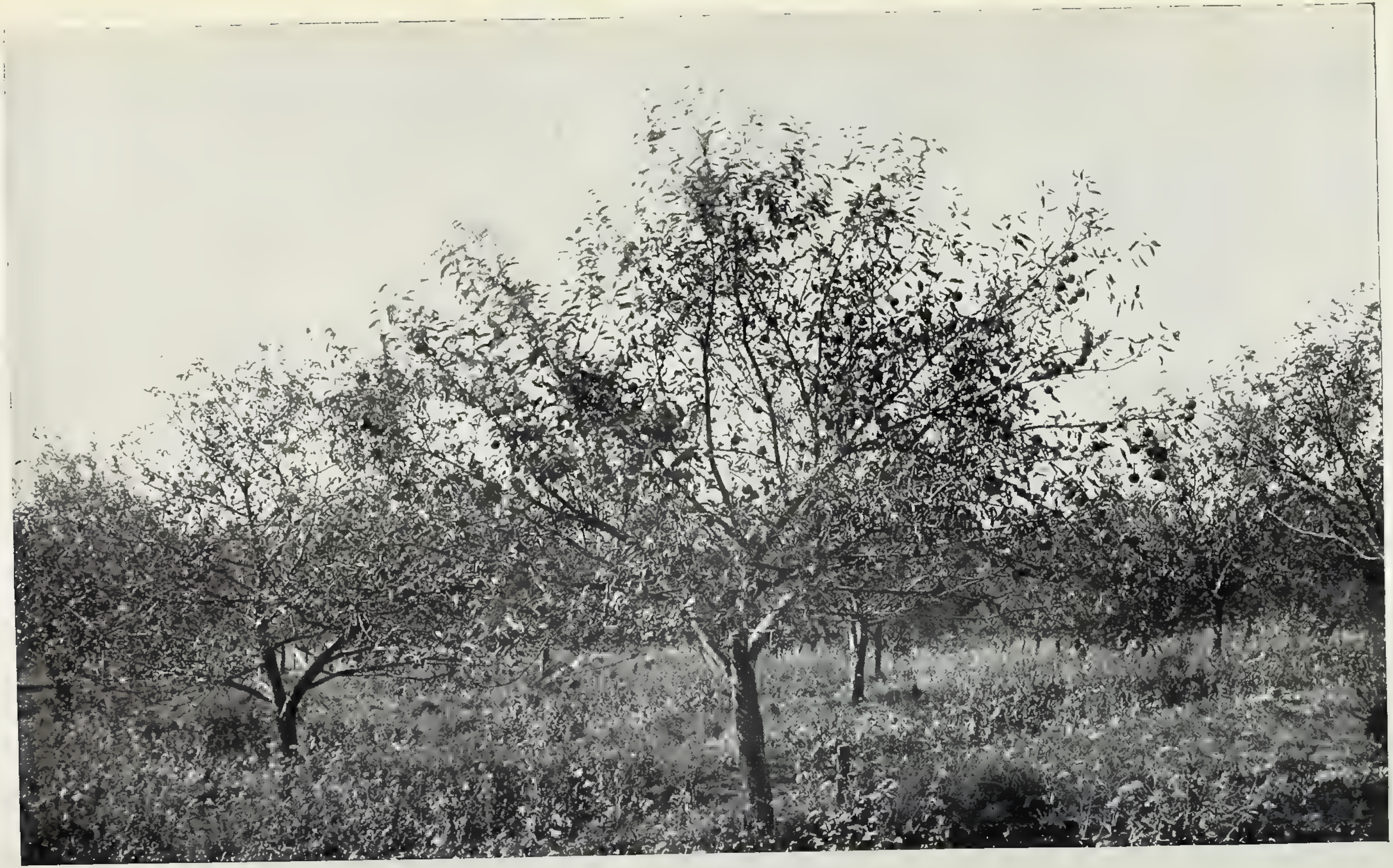

Fig. 56. Defoliation on "Sulfocide" Plot

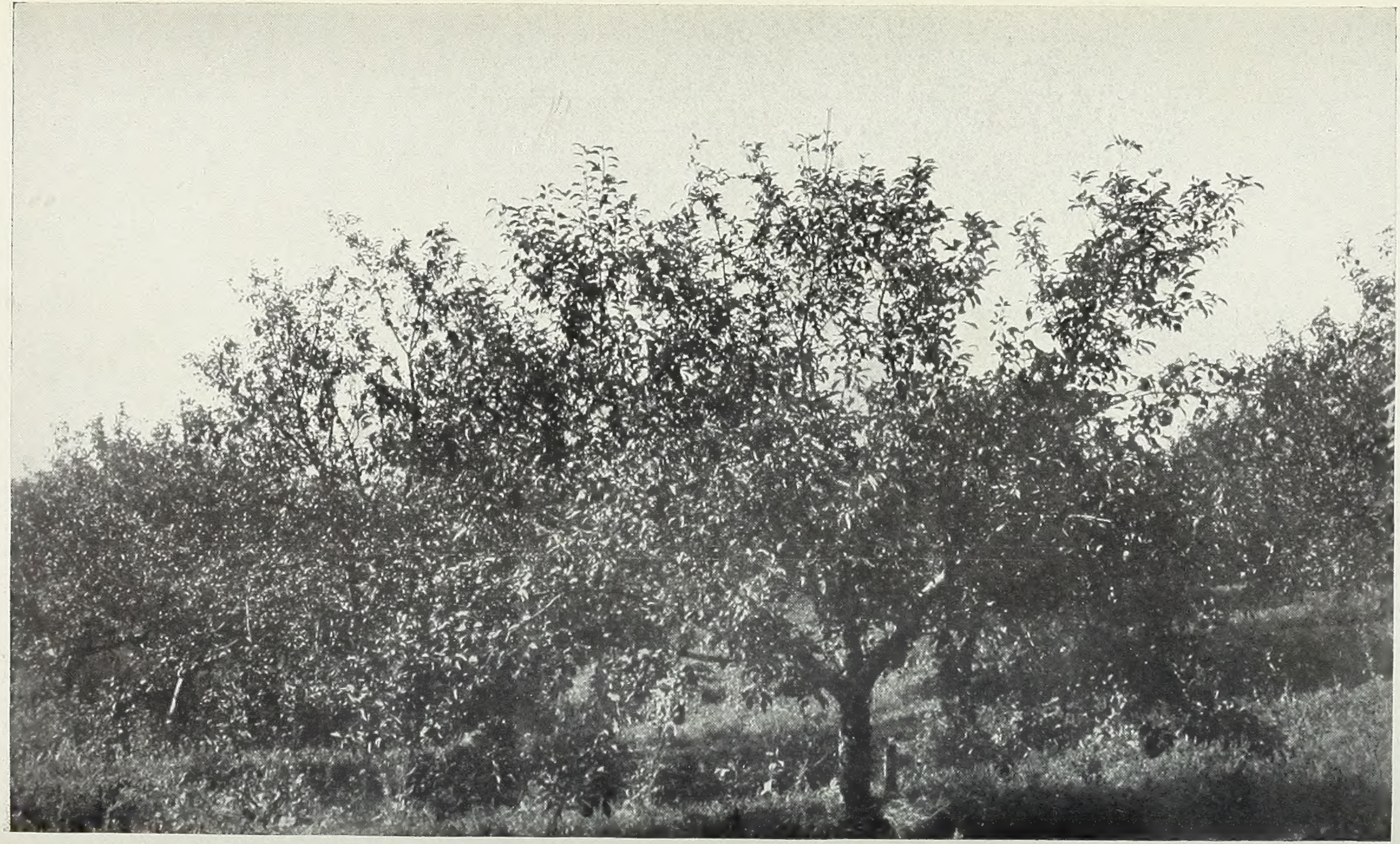

Fig. 57. Home-Boiled Lime-Sulphur Plot

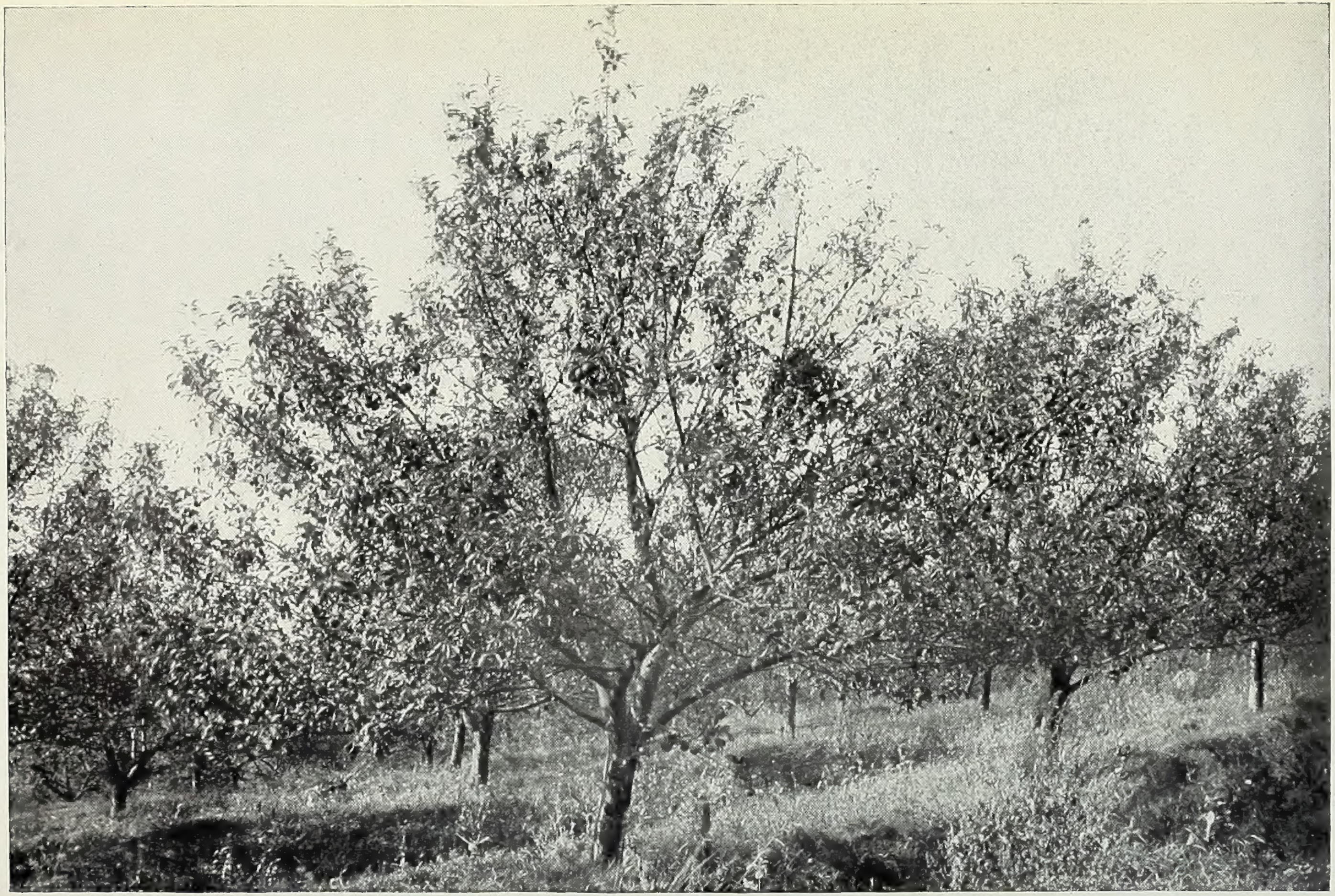

Fig. 58. Partial Defoliation on 4-4-50. Bordeaux Plot